Libby Asbestos Site
Residential/Commercial Cleanup
Action Level and Clearance Criteria Technical Memorandum

WORKING DRAFT 8/19/03

I. INTRODUCTION

In 2002, the U.S. Environmental Protection Agency Region VIII (EPA) began systematic investigation and cleanup of residential and commercial properties in Libby, Montana. The Action Memorandum Amendment dated May 8, 2002 ("the Action Memo") set forth general requirements and reasons for the emergency response cleanup (EPA 2002). These will not be reiterated here. This memorandum describes detailed "action levels" that will be used to determine if a property requires cleanup under the Action Memo and detailed "clearance criteria" that will be used to determine if a cleanup is complete. It also describes the rationale used to establish these action levels and clearance criteria. The Appendix to this memo presents detailed discussion and quantitative screening level estimates of exposure and risk from Libby asbestos in air, dust, and soil.

In this memorandum, the term "cleanup" is used generally to imply some type of response action and does not necessarily imply removal of contaminated material. In some instances, EPA's response action will be isolation or encapsulation of contaminated material. In some cases, where contaminated material is difficult to access or well-contained, and exposure is likely to occur very infrequently or not at all, the material may simply be left in place and documented. Details of EPA's cleanup approach can be found in the Response Action Work Plan (CDM 2003a).

This document first discusses the general decisions that are required for each property, then discusses the action levels that would lead to cleanup actions for each property, then finally discusses clearance criteria that EPA will use to determine when a cleanup action was successful and is complete. Follow up actions are presented last.

II. SAMPLING APPROACH

Throughout this memorandum, general references to sampling and analysis methods are made for simplicity. A detailed discussion of the many sampling approaches, analysis methods, counting methods, sample preparation methods, and quality assurance steps is beyond the scope of this document. Details of EPA's dust sampling and analysis protocol for various situations can be found in the Indoor Dust Sampling and Analysis Plan (EPA 2003). Details of EPA's air sampling and analysis protocol for various situations can be found in the Response Action Work Plan (CDM 2003a). Detail's of EPA's soil sampling strategy for various situations can be found in the CSS SAP and CSS SAP Revision I (CDM 2002 and 2003b), Remedial Investigation SAP (CDM 2003c), and Response Action Work Plan (CDM 2003a).

It is also important to note that EPA's sampling and cleanup program is based solely upon the presence of "Libby asbestos." Libby asbestos is a form of amphibole asbestos unique to the Libby vermiculite deposit and is fundamentally different from more commonly found chrysotile asbestos. Chrysotile asbestos was used in commercial products for decades and is found throughout the environment of the U.S. and developed world. EPA will not base cleanup decisions or take action based upon the presence of chrysotile asbestos not associated with the Libby mine, except where necessary to protect worker safety. Asbestos containing commercial products and materials are regulated through other programs and are generally not subject to Superfund authority.

III. DECISIONS REQUIRED FOR EACH PROPERTY

Each property in Libby generally requires three independent decisions regarding cleanup:

- Cleanup of the attic or interior walls (ATTICS/WALLS)
- Cleanup of the interior living space (INTERIORS)
- Cleanup of outdoor soils (SOILS)

Contamination in one area does not automatically imply contamination in another. For instance, a particular property may require cleanup of an attic but not the interior living space or outdoor soils. Some properties may require cleanup in the attic, interior, and soils. Any combination is possible depending upon the unique conditions of each property.

In 2002, EPA initiated the Remedial Investigation (RI) of Libby residential and commercial properties to determine which properties may require cleanup. The first phase of the RI was called the Contaminant Screening Study (CSS). The CSS was a screening step intended to collect readily available information (through inspections, verbal interviews, and soil sampling) to be used in decision making for each property. The objective was to classify properties as either (1) requiring cleanup, (2) requiring more investigation before a decision can be made, or (3) requiring no further action. The criteria in this memorandum, along with other information, are being used to interpret the results of the CSS and in planning for additional sampling and cleanup. Preliminary results of the CSS (soil samples have not yet been analyzed) are found in the CSS Draft Final Technical Memorandum (CDM 2003b). The Technical Memorandum will be updated and expanded when soil sample results are available. As of this writing, over 1200 properties have been identified that require cleanup, and further investigation will likely yield a few hundred more. The cost of the cleanup program set forth in this and other documents for 1200 properties will be well over $60,000,000. The large scope of the cleanup effort dictates that resources must be used efficiently and that situations presenting higher levels of risk must be addressed first, even considering the unique conditions presented by the Libby site.

It is also important to note that EPA is conducting an emergency response action in Libby. We have determined that many situations constitute an imminent and substantial endangerment to public health and that immediate action is required. Thus, cleanup is beginning before completion of a site specific baseline risk assessment and a full remedial investigation/feasibility study, which is normally used along with other information to establish site specific action levels, clearance standards, and cleanup approach. In the absence of such information, EPA must make an informed decision based upon the information available. No matter the level of information available, we must ensure our decisions are protective, implementable, and cost effective. Upon completion of several emergency response residential/commercial cleanups, EPA will revisit homes to collect samples to ensure our methods of cleanup remain protective over time. This is discussed more in the final section of this memorandum.

Cleanup standards may be revised in Libby upon completion of a baseline risk assessment or receipt of other information. This has two implications. First, some properties will not meet *any* of the criteria for emergency response, but may meet lower (more stringent) standards that may be established in the future (e.g. for soil). These properties will be addressed later. Second, it is obviously inconvenient, impractical, and costly to clean a property twice. Thus, we are attempting to adopt standards and cleanup procedures that ensure we conduct substantial cleanup operations only once at the vast majority of properties. If a property meets *any* of the criteria for emergency response cleanup, we are cleaning the property to a degree that would likely be protective even if standards are lowered in the future (e.g. we remove all detectable surface soil contamination, not just that greater than 1%). This approach is cost effective and protective.

IV. ACTION LEVELS

Any one of the following conditions will generally trigger emergency response cleanup for that portion of the property and cover most circumstances likely to be encountered.

ATTICS/WALLS

- Visual confirmation of vermiculite insulation

INTERIORS

- Visual confirmation of vermiculite in the living space
- Concentration of LA in a settled interior dust sample greater than 5000 Libby asbestos (LA) structures per square centimeter (s/cm2) using AHERA counting methods. This will be referred to as 5000 AHERA s/cm2. AHERA counting methods are very similar to those used in ISO 10312.

Each level, or floor, in a building's interior is evaluated separately. Libby sampling data has shown that in most cases, only one floor is highly impacted (e.g. material tracked in from outside on the ground floor). This sampling approach allows us to focus interior cleanup resources on only the portion of the interior where there is a clear problem. It also increases the protectiveness of the cleanup by using the maximum sample result to determine if cleanup is necessary, rather than the average of all samples.

More Processing materials

SOILS

- Visual confirmation of vermiculite in "specific use areas." A specific use area is defined as a garden, former garden, planter, or other defined area of a yard likely to receive significant use and generally not covered with grass. Any LA
- Concentration of LA in yard soil by any method greater than or equal to 1% Libby asbestos by mass.

It is important to note that much of EPA's investigation and cleanup approach is geared toward finding and addressing *sources* of LA. The major sources in the area, such as the mine, the screening and export plants, and large vermiculite piles, have already been isolated or cleaned up. Remaining sources, on a much smaller scale, may include (but aren't necessarily limited to) vermiculite insulation, raw vermiculite, or soils with elevated levels of LA. Sources, through a variety of mechanisms, can serve to contaminate indoor dust and have the potential to release significant amounts of LA when disturbed. Source removal or isolation ensures that loading to household dust (one of the most significant exposure pathways over a lifetime) is stopped immediately. In the absence of sources, levels of LA in indoor dust (even absent EPA intervention, which is not the case here) will decrease on their own over time. Indeed, one can surmise that concentrations of LA in ambient air and indoor dust in Libby were much higher in the past when mining and processing facilities were still in operation.

Similarly, EPA's cleanup approach considers not only the presence of source materials and the concentration of LA within them, but also the likelihood that these source materials may be disturbed. This is particularly true for soil contamination. For instance, soils with lower concentrations of LA (generally less than 1% Libby asbestos) are likely to only cause excessive risk only if disturbed or encountered frequently and over long periods of time. Thus, in areas where such soils are not likely to be encountered frequently, such as at depth, or below permanent cover areas such as driveways or foundations, these materials will generally be left in place. Conversely, materials with higher concentrations of LA (generally equal to or greater than 1% Libby asbestos) are likely to be of concern if exposure is frequent, and may present risks even if encountered only intermittently. In some situations, EPA may seek to remove or further isolate such materials to prevent even infrequent exposures, depending on the situation.

V. ACTION LEVEL RATIONALE AND DISCUSSION

ATTICS/WALLS

EPA has determined that vermiculite insulation is a potential source of LA and that visual confirmation of vermiculite insulation is sufficient justification for action. The rationale for this decision is described in the Action Memo and will not be reiterated here. During the CSS, EPA is visually inspecting attics, and some walls, for the presence of vermiculite insulation. Only in special circumstances will samples be collected in attics or walls to determine if cleanup is necessary.

C

If contact Frequent
LA < 1% to be removed

Cleanup is not contingent upon the measured concentration of Libby asbestos in insulation. Past sampling by EPA in Libby has clearly shown that while LA concentrations in bulk vermiculite insulation may vary considerably (presumably even within the same home), all or most vermiculite insulation has the ability to release LA when disturbed and that frequent disturbance can lead to excessive risk (Weis 2002). Because concentrations can vary considerably, and because even samples of bulk insulation that were measured as "non-detect" by polarized light microscopy or transmission electron microscopy have been shown to release measurable Libby asbestos to air (presumably due to the highly friable nature of ~~expanded vermiculite~~ LA), further large-scale bulk sampling of insulation was not considered necessary or cost-effective. Such sampling would be expensive and is likely to provide no new information in a timely manner. Additional rationale for this decision is also presented in the CSS SAP (CDM 2002).

Cleanup is also not contingent upon the volume of vermiculite insulation, though it may affect the scope of response. Similarly, remnants of vermiculite in an attic may indicate inadequate prior removal of vermiculite insulation. In some cases, dust samples may be collected to determine the efficacy of any suspected past insulation removals.

Cleanup of vermiculite insulation is not contingent on the condition of the property or dust levels in the interior of the property, though in some cases this may affect the action taken. For instance, vermiculite insulation in a structurally sound wall may be left in place and sealed, whereas vermiculite insulation in a wall that is leaking and in poor condition may be removed. Some walls, or even properties, may require demolition.

INTERIORS

Exposure to contaminated indoor dust, even dust with a relatively low level of LA, is an important exposure pathway. This is because people spend most of their life in their home and exposure occurs continually. However, indoor dust is a *secondary* medium - it can only become contaminated through disturbance of some other source of LA. Again, the most important step EPA can take to break this pathway is to address the sources that are contaminating indoor dust or have the potential to contaminate indoor dust in the future. At Libby, EPA is not relying upon measured dust levels to decide if sources must be addressed - our approach at this point is to find and address sources with the potential to significantly contaminate indoor dust regardless of current indoor dust levels. In this regard, indoor dust action levels should not be considered triggers for overall cleanup, but only a trigger for a aggressive interior cleaning by EPA. This differs from other cleanups where actions to address a source are contingent upon the results of air or dust samples. This approach ensures that situations that may present a short-term exposure hazard are addressed as quickly as possible.

During the CSS, EPA is visually inspecting interiors for the presence of visible vermiculite, such as insulation that has trickled into the living space from the attic or walls. If vermiculite is observed in a particular level, cleanup of that entire level is triggered and no dust samples are collected. If vermiculite is not observed on a particular level, a dust sample is collected on that level to determine if EPA cleanup is necessary.

Using visual observation of vermiculite as a trigger for cleanup has several benefits. First, it is conservative and protective. It is possible that in some situations, there are relatively low levels of Libby asbestos in the living space associated with the visible vermiculite (e.g. if a dust sample were collected, it would not contain greater than 5000 AHERA s/cm2). Second, it eliminates the need for collection and analysis of a dust sample. The only potential drawback of this approach is that in some circumstances EPA may expend resources to clean an area that did not exceed 5000 AHERA s/cm2. However, this drawback is offset by the actual cost savings in sample collection and analysis and community involvement costs associated with dealing with issues of perception. It is also important to note that EPA does not assert that dust concentrations of less than 5000 AHERA s/cm2 present no risk, or that all dust concentrations above 5000 AHERA s/cm2 do. Indeed, our approach for situations where indoor dust levels are below 5000 AHERA s/cm2 is to ensure that potential Libby asbestos sources are removed or isolated regardless of indoor dust levels, and to provide the property owner a High Efficiency Particulate Air (HEPA) filter equipped vacuum cleaner for use at the property. The details and rationale for this program are discussed in the Libby Asbestos Site HEPA Vacuum Program Memo (Volpe 2003). More discussion on the risks presented by indoor dust is found in the Appendix.

EPA considered establishing action levels based on disturbed air concentrations to determine if interior cleanup was necessary. However, pre-cleanup air sampling was considered impractical for the scope of cleanup faced in Libby. To be effective and consistent, residents would have to be kept from the home for an extended period so that EPA could achieve a controlled environment and actively disturb the dust. On a scale of thousands of homes, this is would be difficult to implement. Additionally, air samples are far more labor intensive to collect than dust samples, making dust samples more cost effective.

However, establishing action levels based upon indoor dust levels is not straightforward. There are two primary reasons for this:

- Unlike air, there are no established regulatory or health-based standards for indoor dust.
- EPA's Phase II investigation in Libby showed that it is not straightforward to draw correlations from indoor dust asbestos concentrations to airborne asbestos concentrations (which are what are actually breathed in by a resident and for which there are health-based and regulatory standards). There are too many confounding variables affecting resuspension - most importantly it is highly behavior specific. Development of a site-specific correlation would require at least hundreds of samples. This is discussed more in the Appendix.

When selecting 5000 AHERA s/cm2 as a trigger for interior cleaning, EPA considered several factors:

- Again, at Libby, EPA is addressing sources of LA regardless of indoor dust levels. In contrast, indoor dust or air concentrations of asbestos have been used elsewhere to determine if source removal or isolation is necessary at all. In Libby, EPA is choosing to be more protective with regards to source material. We feel that this is the most important step EPA can take to minimize future exposures, especially those likely to occur on a frequent basis.

- Screening level risk estimates for exposure to household dust were prepared by EPA Region 8 and are presented and discussed in the Appendix. These estimates, using available data and two risk assessment models, are intended to be very conservative. The uncertainties associated with the risk estimates are discussed in the Appendix. The estimates suggest that risk levels for a resident exposed *continually* to an average indoor dust level of 5000 AHERA s/cm2 throughout the home for 70 years are greater than 1 additional cancer expected per 1000 people. EPA generally takes action if risk estimates exceed a 1 in 10,000 level. In the cases where dust levels exceed 5000 AHERA s/cm2 in at least one level of a property, in addition to addressing sources, EPA feels that aggressive interior cleaning is warranted to ensure protectiveness and to stop even short-term exposures. RI

  <5000 Risk Ass Risk Ex

- Interior cleaning by EPA is costly. Cleaning all of the interiors of all houses in Libby would be very expensive and significantly extend the cleanup duration. Some cutoff must be established above which such time-consuming and costly cleanup is warranted, so that available resources can be directed to source removal and the situations presenting the most risk. Below this threshold, less aggressive measures must be considered. For lower dust levels which present lower risks, once sources are addressed by EPA, dust levels will should decline. A resident using a HEPA vacuum and wet-wiping surfaces can greatly accelerate the process and achieve similar success to that of an EPA cleanup at a fraction of the cost and effort.

- Due to its use for decades and natural occurrence, asbestos is present in the air and dust of all industrialized countries, specifically in urban environments. Based on numerous dust sampling events across the country, Millette (1994) has grouped typical results into High, Medium, and Low categories. Millette classified levels on the order of 100,000 s/cm2 as "high," levels on the order of 10,000 s/cm2 were classified as "medium," and levels on the order of 1,000 s/cm2 as "low." These figures are not based on risk and do not imply that "low" concentrations are safe, but they are indicative of typical dust concentrations workers and residents are exposed to around the country. Selecting a level for a *maximum* dust concentration a resident may be exposed to on the low end of this scale ensures that Libby residences will be cleaner than many environments faced across the country, and removal and isolation of sources ensures it will become even cleaner over time.

  Amphibole vs. Chrys.

- Many asbestos researchers believe that only asbestos structures greater than 5 microns in length cause appreciable risk and that smaller structures can be effectively expelled from the body. Even for those who disagree, most agree that longer fibers present substantially more risk than smaller fibers. Traditionally, phase contract microscopy (PCM) was used to measure asbestos in air, and an asbestos "fiber" was counted only if it was at least 5 microns in length, had a length to width aspect ratio of 3:1, and were thick enough to be seen (about .25 microns in diameter). Many current regulatory standards and risk assessment methods are still based on counting only fibers that meet this minimum size and aspect ratio criteria, including the current risk model used by EPA for asbestos. Though often measured differently today, fibers meeting these requirements are sometimes referred to as PCM Equivalent (PCME) fibers. Based on hundreds of air and dust samples collected in Libby, it is evident that approximately 6/10 of all fibers observed in Libby are shorter than 5 microns or do not meet other criteria for a PCME fiber, but would be counted as a structure using other counting methods. Counting all AHERA structures, as opposed to only PCME fibers, allows us to account for the additional risk these fibers may impart as well as effectively achieving a lower detection limit for PCME fibers. These relationships are described more in the Appendix.

- Few large scale indoor dust cleanups have occurred, but a large scale interior dust cleanup is currently being conducted in the area surrounding the former World Trade Center (WTC), where many apartments were impacted by dust during the collapse. Sampling and cleanup of individual apartments must be requested before any action is taken. This is different from Libby where EPA is systematically addressing all properties (though cleanup is still voluntary). At the WTC site, EPA and other organizations have opted not to use samples of settled dust to determine if interior cleaning is necessary or complete. Instead, if a resident requests sampling, aggressive air sampling similar to that being used in Libby, is performed to determine both if cleanup is necessary and when it is complete. The numerical levels used for apartment clearance around the former WTC are discussed more in the Section VII below.

- The sensitivity of the analytical methods EPA is using to quantify asbestos in dust vary based on several factors, but are typically on the order of 1000 AHERA s/cm2. Detection of asbestos concentrations below this level in dust require more extensive analysis and considerably more costly to achieve.

- EPA considered the need for testing and removal of carpets and textile (such as drapes). In general, EPA has elected not to sample actual carpet or textile material, but rather will rely on settled dust samples and aggressive air clearance samples to measure the amount of asbestos that has been released, or can be released, into air. If asbestos is being released to ambient air from carpets, one would expect to find it in settled dust. While carpet removal or wet cleaning would remove more asbestos bound within the carpet, it is not clear that this would affect the amount of asbestos likely to be released with normal disturbance. Such an approach would also be extremely costly and time consuming. In certain circumstances, EPA may remove carpet or other textiles if clearance standards cannot be achieved.

- EPA considered the need for sampling and cleaning of heating and air conditioning ducts and systems. Similar to carpets, sampling and cleaning of ventilation systems would be extremely difficult to achieve, and the effect of such recessed areas on the ambient environment does not appear to be profound in Libby. If forced air systems were effectively re-suspending and recycling contamination through homes, we would expect to see uniform patterns of contamination within a particular home. As stated previously, in most circumstances elevated dust levels are confined to one area of the home.

SOILS

During the CSS, EPA is visually inspecting properties for vermiculite in soils. If vermiculite was observed in a particular area (e.g. front yard, side yard, garden, etc), no soil sample was collected in that area. If vermiculite was not observed, a soil sample was collected from that area. Past observations showed that when visible vermiculite was noted, samples confirmed the presence of Libby asbestos approximately 70% of the time using polarized light microscopy (PLM). If more sensitive methods were used, this number may have been higher. Thus, the presence of visible vermiculite was considered an indicator for the presence of LA and material that could serve as a potential source of LA to air or dust. Using visible vermiculite as a trigger had the benefits of being conservative and protective (e.g. it is likely that some or many cleanups will occur for soils that have less than 1% LA) and simple (this eliminated the need for collection and analysis of thousands of samples). This is discussed more in the CSS SAP (CDM 2002). Such an approach also addresses the community perception that all vermiculite is hazardous and should be removed. This same general approach of using visual observations as a trigger for cleanup was also employed during the remediation of other large source areas in Libby, such as the screening plant, export plant, and flyway property. It will also be used for the remediation of the railyard in Libby by Burlington Northern Santa Fe (BNSF Workplan 2002).

While conducting the CSS, EPA discovered three key points regarding visible vermiculite in soils:

- The number of properties with visible vermiculite in soils was far greater than originally anticipated.
- While there were exceptions to the trend, the amount of visible vermiculite varied considerably from a few flakes over a generally wide area to very concentrated amounts in small areas. The CSS had no systematic way to account for this or differentiate it other than sampler observations.
- There were several instances where vermiculite was observed in areas that were difficult to access and where exposure was likely to occur infrequently, if at all. There are likely many more of these situations that were not discovered during the CSS that will become apparent through subsequent, more detailed investigations or during cleanup.

It is clear that attempting to clean every flake of vermiculite and every location where vermiculite is encountered is fundamentally impossible. Because of this, EPA reevaluated its initial approach to visible vermiculite in soils. Rather than assuming that all occurrences of visible vermiculite would result in cleanup, only significant occurrences in specific use areas would lead to cleanup without additional sampling. Yard areas would be revisited and sampled to determine the presence of LA and the need for cleanup, and areas that were difficult to access would be evaluated based upon the particular situations. There are several reasons for this:

- Vermiculite was generally used as a soil amendment in specific locations such as gardens. Because of this, the likelihood of elevated levels of vermiculite and LA there is much greater than for yards. Observations in the CSS showed this generally to be the case.
- Specific use areas are more likely to lack ground cover, such as grass, that would minimize creation of dust.
- Specific use areas are likely to be actively and frequently disturbed through activities such as gardening.
- Specific use areas are generally small and can be cleaned up quickly at low cost. A large scale sampling program is not justified for these situations, considering that for many of these situations (CSS SAP, CDM 2002) sampling will confirm the presence of LA. Cleaning up entire yards, large portions of yards, or areas that are infrequently accessed or disturbed is a much larger and expensive task and additional sampling is warranted.

In the absence of visible vermiculite in a specific use area, EPA has selected a concentration of 1% LA or greater as a trigger for emergency response soil cleanup in yards or gardens. When selecting this level, EPA considered the following key factors.

- Materials containing 1% or greater asbestos are currently regulated as asbestos containing materials and can clearly act as an ongoing source of LA. This standard was applied during previous emergency response cleanups in Libby.

- Screening level risk estimates for exposures at a home with contaminated soil were prepared by EPA Region 8 and are also presented and discussed in the Appendix. These estimates, using available data and multiple risk assessment models, are intended to be very conservative. The estimates suggest that risk levels for a resident living at a property with a level of 1% asbestos in the soils of the entire yard for 70 years are on the order of 1 additional cancer expected per 1000 people. Again, EPA generally takes action if risk estimates exceed a 1 in 10,000 level.

- Inexpensive analytical methods currently available (e.g. PLM) can detect levels of 1% or greater with reasonable accuracy. Site specific improvements in the use of PLM at Libby have led to much higher confidence in sampling results and the ability to detect and quantify asbestos levels in soils of less than 1%. EPA is currently testing several methods to determine their ability to detect and quantify levels less than 1%.

Again, it is important to note that in certain circumstances, soils with less than 1% Libby asbestos may be remediated under the current emergency response program. If a portion of property meets either emergency response trigger for soils (visible vermiculite in specific use areas or LA greater than 1%), EPA will remediate all soils at the property with any detectable LA. This is primarily so that we will not have to re-clean the property later if a lower actioin level is adopted (e.g. after risk assessment) and to ensure bulk sources are addressed. This is considered protective (we do not wish to wait several years until final standards are adopted to address emergency situations) and cost effective. Our approach, however, is to target properties where this is *not* the case first, so that we are only cleaning soils that meet the emergency response action levels. This is also consistent with previous cleanups in Libby.

VI. CLEARANCE CRITERIA

Cleanup of a portion of a property is considered complete and the property "clean" when all of the following criteria are met.

ATTICS/WALLS

- No visible vermiculite remaining in accessible areas
- Any vermiculite remaining is well-contained
- The *average* of approximately 5 samples of disturbed air collected in the attic indicate less than 0.01 AHERA structures per cubic centimeter of air (AHERA s/cm3).

INTERIORS

- No visible vermiculite remaining in accessible areas or living space
- *Each* of approximately 5 samples of disturbed air on the level(s) or floor(s) cleaned are below the detection limit of the AHERA TEM method (approximately 0.005 AHERA s/cm3).

SOILS

- No substantial visible vermiculite or waste material remains in specific use areas
- In excavated areas, soil samples collected at the depth of cut are non-detect for LA by PLM. If maximum depth of cut is reached (12 inches for yards, 18 inches for specific use areas), soil samples collected at the bottom of excavation must be less than 1% LA by PLM. Clean backfill is then placed over the excavation. This approach ensures that no detectable LA (by PLM) remains to a depth of 12-18 inches, but allows small amounts of LA to remain well below ground surface, where soil is unlikely to be disturbed. More information on the clearance sampling approach for soils is found in the Response Action Work Plan (CDM 2003a).

If these criteria are not met, re-cleaning or other steps may occur, and the process is repeated. If any situations occur where clearance criteria cannot be met, unique approaches may be considered.

VII. CLEARANCE CRITERIA, RATIONALE AND DISCUSSION

ATTICS and INTERIORS

Attics and interior living spaces are cleared using the same approach (based generally upon procedures outlined in the Asbestos Hazard Emergency Response Act (AHERA), but with different final numerical standards to account for the different amount of exposure likely for each. Once physical cleanup is complete, and visual inspection shows that all vermiculite is removed or contained, each individual space (e.g. the attic or particular floor of the home) is blown with a 1 horsepower leaf blower for several minutes. The action of walking through the living space and aggressively blowing dust from all surfaces, effectively simulates a very high-end exposure. Following this action, fans are set up in the space to keep the air circulating, and air samples are collected.

EPA considered the use of settled dust samples for a clearance criteria, rather than aggressive air sampling. However, because the property was just cleaned, a settled dust sample would likely not be representative and is not as directly correlated with risk estimates as air concentrations. The use of aggressive air sampling is also feasible in this situation because the resident is already relocated and a controlled environment is present.

When EPA selected these clearance criteria, we considered several factors:

- Sampling occurs after the source is removed and is conducted after the dust throughout the space is aggressively disturbed. These conditions will not simulate normal living conditions suspected in the future, but rather approach worst-case conditions. The primary intent of the all clearance sampling is to ensure that sources were effectively addressed, not to demonstrate an expected long-term exposure level.

- Requiring a non-detect for *each* of five samples in the living space, as opposed to calculating the *average* of the five samples, effectively increases the protectiveness of the cleanup in the interior living space. Under this scenario (all five non-detects), the absolute maximum concentration in any one sample that is possible is less than 0.005 AHERA s/cm2, but average exposure concentrations across the living space are effectively less than approximately 1/5 the detection limit of a single sample, or less than 0.001 AHERA s/cm3.

- Screening level risk estimates for exposures to asbestos contaminated air were prepared by EPA Region 8 and are also presented and discussed in the Appendix. These estimates, using available data and multiple risk assessment models, are intended to be very conservative. The estimates suggest that risk levels for someone exposed *continually* to an air concentration of .001 AHERA s/cm3 for 70 years are on the order of 1 additional cancer expected per 10,000 people. Again, EPA generally only takes action if risk estimates exceed a level of 1 additional risk in 10,000 people. Actual exposure levels, and associated cancer risks, will be considerably lower.

- Because exposure in attics is likely to occur far less frequently than in main living spaces, higher numerical standards are applied and a mean concentration is used. The clearance criteria for interior living space in Libby are currently about 5-10 times more stringent.

- Due to its widespread use for decades and the fact that it is a naturally occurring mineral, asbestos is present in the air and dust of all industrialized countries, specifically in urban environments. And while there is no single widely acknowledged "background" level of asbestos, many studies have quantified ambient air concentrations in urban environments. Several studies have shown levels in urban or industrial environments on the order of 0.01 s/cm3 or higher (Murchio, 1973; John et al, 1976; Chatfield, 1983). This is approximately ten times the clearance level for Libby. This does not imply these levels are safe or acceptable, but it does illustrate that all urban areas, and many rural homes, are impacted by asbestos to some degree due to its widespread use over time. We also know that many homes across the country were insulated with vermiculite insulation and will likely not be cleaned up. At the completion of the emergency response action, properties in Libby will be cleaner than many urban areas and residential homes across the country with regards to asbestos.

- The current standard for worker protection, the Permissable Exposure Limit (PEL) established by the Occupational Safety and Health Administration (OSHA), is no greater than 0.1 PCME s/cm3 for an eight hour exposure. At Libby, this would equate to a standard of approximately 0.25 AHERA s/cm3 (considering that roughly 2/5 of all fibers observed in Libby meet the size requirements to be a PCME fiber). While few consider this level protective, and OSHA clearly states that it is *not* intended to be fully protective, it nonetheless is a current standard which governs worker exposure. The clearance standard for Libby interior cleanings, after sources are removed, is approximately 1/250 this amount.

- While the scope of the AHERA clearance protocol and its application are beyond the scope of this memo, it can be generalized to say the current clearance standard for asbestos removals in schools is approximately .02 AHERA s/cm3 of air (commonly expressed as 70 AHERA structures per square millimeter of sample filter or s/mm2). This value is compared against the *average* of multiple samples, whereas in Libby interiors we compare each of approximately five samples to our clearance standard. Many believe that the AHERA clearnce standard is not fully protective and it is often misused. Nevertheless, it is the current standard which determines if a professional asbestos abatement at a school is complete. EPA's effective clearance criteria of less than

0.001 AHERA s/cm3 is approximately 1/20 of this level.

- For the WTC apartment cleanups, EPA is using a clearance level of 0.0009 PCME s/cm3 (for exact details of the WTC cleanup and sampling program, see ____________). When Libby's maximum single sample interior clearance criteria of .005 AHERA s/cm3 is converted to PCME, it is equivalent to roughly .002 PCME s/cm3. When Libby's five sample effective average interior clearance level of .001 AHERA s/cm3 is converted to PCME, it is is equivalent to roughly .0004 PCME s/cm3. With a difference of only and .0011 s/cm3 and .0005 s/cm3 respectively, the criteria used at the WTC is roughly the same as that used in Libby.

- The detection limit of the AHERA method for a single sample is approximately 0.005 AHERA s/cm3. Our criteria requires a non-detect for each sample for interior clearance, meaning no fibers were observed in the analysis using procedures set forth in the AHERA method. Detection of asbestos concentrations below this level in air is very difficult, especially under disturbed conditions, and the effort required is considerably more costly than the AHERA method.

- At this point, EPA does not assert that a non-detect for indoor clearance implies that no Libby asbestos remains, or that an indoor air concentration of 0.001 AHERA s/cm3 or below presents no risk. Further, EPA emphasizes that risk estimates are not exact. While risk estimates are intended to be conservative, there are many scientific disagreements regarding Libby asbestos measurement and risk assessment, and many uncertainties in the risk assessment process. Similar to the discussion on dust, any Libby asbestos fibers remaining after clearance sampling are due to low level residual contamination. In the absence of a source, these levels must decline, though at what rate is unknown. To ensure these levels decline and risk is minimized, and to deal with any other sources of Libby asbestos that may be present in the property, EPA will provide a HEPA vacuum to property owners of all properties EPA has cleaned (in addition to other properties that were not cleaned). Again, details of the scope of the HEPA vacuum program are found in HEPA Vacuum Program Memo (Volpe 2003). Additionally, post-cleanup sampling is planned to ensure that indoor dust levels remain low or decline as expected. This is discussed more in the final section of this memorandum.

SOILS

Soils requiring cleanup are cleared using an iterative approach. Limited excavation of the defined area occurs until no visible vermiculite is observed, or until the native soil horizon is reached. At this point, a representative number of soil samples are collected dependent upon the size of the excavation. If these samples are non-detect by PLM, the excavation is considered complete and the area is backfilled with clean soil. If LA is detected by PLM, excavation continues until the maximum depth of excavation is reached (12 inches for general yard areas, 18 inches for specific use areas). At this point, excavation would only proceed further if gross contamination is observed or PLM samples clearly indicate higher levels of LA (greater than 1%).

When establishing this approach, EPA considered the following factors:

- Nearly all exposure results from near-surface soils. These soils generate dust and are often actively disturbed. In most circumstances, contamination will also be limited to near surface soils. To ensure resources are focused on the soils that are most likely to cause impacts, a maximum depth of excavation was established at 12-18 inches. These depths are based on the depth that typical residential activities may intrude into the soil (such as planting, rototilling, or installation of sprinklers). Slightly elevated levels of LA are considered acceptable at this depth, where disturbance will occur very infrequently if at all.
- More sensitive analytical methods that detect lower levels of LA will be used for surface soil sampling (where frequent, ongoing exposure and dust generation occurs) to determine which specific areas require cleanup. However, these methods require off-site preparation and analysis and would require several weeks to provide results. Once cleanup begins, it is unfeasible to leave the excavation open for the time needed to use these types of analysis. Thus, PLM, which is inexpensive and can be performed on-site in a matter of hours, is considered acceptable for clearance of soils at depth, for evaluation of soils that are in areas that are generally inaccessible, or to determine if short-term exposure hazards are present.

VIII. FUTURE ACTIONS AND FOLLOW UP

Based on the information available, EPA has developed an emergency response cleanup program that:

- focuses on elimination of exposures that are likely to occur frequently and continually over time;
- removes the vast majority of identified LA sources, with special focus on sources with higher concentrations that are likely to cause impacts with even short-term exposure;
- isolates sources that are impractical to remove;
- addresses the highest exposures in the quickest manner possible;
- leaves low residual levels of LA and minimizes the likelihood of future re-cleaning;
- considers the many uncertainties regarding asbestos analysis and risk assessment and employs many strategies (from sample collection to cleanup) to help overcome the uncertainties that suggest risks could be higher than anticipated ;
- reduces future management needs; and
- is protective, cost-effective, and implementable.

We believe this program is among the largest and most protective asbestos cleanups ever conducted in the U.S. and will leave Libby cleaner and safer than many areas of the country. In fact, vermiculite insulation from Libby was used throughout the country and will likely not be systematically removed elsewhere. Similarly, Libby vermiculite was used in other products across the country that will not be individually investigated or addressed. Due to the magnitude of the exposures that have occurred in Libby in the past, and the clearly elevated levels of disease and mortality observed in Libby, this level of response is considered essential.

However, EPA recognizes the program does not completely eliminate all potential exposure to LA in Libby. Indeed, such a program is impossible to fund or implement. Because of this, future management and review will be required to ensure the long-term protectiveness of the remedy. Nearly all cleanups require some level of long-term management. At Libby, EPA is already taking several steps to address this issue:

- Again, we are providing HEPA vacuums and interior cleaning guidance to residents so they can immediately, and continually, address low levels of residual contamination and any particulate contamination that may be reintroduced later. We will provide guidance on additional steps residents may take to increase/maintain the cleanliness of their home and to increase their confidence in the safety of their home.
- EPA, in conjunction with MTDEQ and local government, will develop a long-term operations and maintenance (O&M) plan to deal with future management issues. Key points of this plan will likely include ongoing education, guidance for residents encountering or working with vermiculite in the future, and a management system for any necessary removals of vermiculite including cleanup assistance and disposal capacity at the Lincoln County landfill.
- Most importantly, after the first set of cleanups in 2003, as part of the Remedial Investigation, EPA will institute a monitoring program for properties that underwent cleanup. Not all properties will be visited, but a sufficient number to draw statistical conclusions will be sampled. This monitoring will measure actual dust and air levels, allowing EPA to (1) determine the efficacy of the cleanups after some time has passed, (2) test assumptions that affect the cleanup approach (e.g. Have dust levels declined? Have textiles and carpets that were not removed affected ambient conditions? Have heating and ventilation systems reintroduced contamination?), and (3) provide actual exposure data for use in the baseline risk assessment for the site. Based upon this sampling, it is possible that the cleanup approach may be modified, and it is possible some properties will require some level of re-cleaning. However, EPA believes we have developed a program that minimizes this possibility.
- Using the best available science and data, including the results of a site specific animal exposure study, a baseline risk assessment will be completed for the site, and final cleanup goals for soil, air, and dust will be established. These will be compared to the measured residual levels at properties where cleanup has occurred, and levels at properties that did not meet the criteria for cleanup, to ensure that all necessary cleanup occurs and that final conditions are protective. The final decisions and actions for the

Libby cleanup will undergo extensive public review and comment.

REFERENCES TO BE ADDED

DRAFT -- FOR USEPA REVIEW ONLY

APPENDIX 1

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APPENDIX 1

SCREENING LEVEL ESTIMATES OF EXPOSURE AND RISK FROM LIBBY AMPHIBOLE IN AIR, DUST, AND SOIL

NOTE: All numeric values derived from the database are DRAFT and are subject to revision pending changes in the database or revision of data selection procedures.

1.0 INTRODUCTION

This appendix is a description of the methods used by EPA to perform a screening-level evaluation of the potential risks of cancer to residents in Libby, MT, from inhalation exposures to amphibole asbestos fibers in air. For convenience, amphibole fibers of this type are referred to as Libby Amphiboles (LA). At present, quantitative methods are not available for estimating the level of non-cancer risks from asbestos exposures.

The methods used in this appendix to evaluate risks from asbestos in air are the same as those that have been used previously (Weis 2000, 2001a, 2001b), but take advantage of new information on concentration and particle size distribution derived from site-specific studies. In addition, the methods used here begin to assess the relationship between asbestos concentrations in various source media (indoor dust, outdoor soil) and resultant health risk to residents. The purpose of this evaluation is to provide risk managers with a frame of reference for judging the magnitude of cancer risk associated with varying levels of contamination in these source materials, and to support the establishment of action levels for the on-going residential/commercial cleanup in Libby.

2.0 BASIC APPROACH

Risk from asbestos is associated mainly with inhalation exposure of suspended asbestos fibers. Because asbestos fibers are heavier than air, they do not occur in air unless they have been released from some type of source material by a disturbance:

Source -----> Air ------> Inhalation Exposure ----> Increased Cancer Risk

The concentration of fibers that occur in air following disturbance of a source and the resultant level of human exposure and risk depend on a very wide variety of highly variable factors, including:

- the concentration of fibers in the source material
- the nature of the disturbance of the source
- the physical properties of the source
- the volume of air into which the fibers are released
- the air flow or ventilation rate in the area where fibers are released
- the particle size distribution of the released fibers
- the frequency and duration of the release
- the frequency and duration of human exposure in the area where release has occurred

Because of these many factors and the wide range of values that each may assume, the ability to predict risk to a resident based only on a measure of the concentration of fibers in the source material is very limited. Conversely, the ability to specify a concentration of fibers in the source material that is "safe" is also very difficult. Nevertheless, if reasonable estimates are made for all of these variables, it is possible to derive a screening-level estimate of the "safe" concentration of asbestos in source materials. While uncertain, such an estimate does provide a useful frame of reference that may be helpful to risk managers faced with the responsibility for deciding which sources require remediation.

3.0 RISKS FROM ASBESTOS FIBERS IN AIR

3.1 Inhalation Risk Models

Information on the quantitative relationship between inhalation exposure to asbestos and increased risk of cancer (mesothelioma and/or lung cancer) are based mainly on studies of workers who have been exposed to various types and levels of asbestos in the workplace. Most of these studies estimated the concentration of asbestos in air using phase contrast microscopy (PCM). In order to be counted as a PCM structure, a particle must have an aspect ratio (length divided by width) of at least 3:1, must have a length of 5 um or more, and must be thick enough to be detectable under PCM (about 0.25 um or more). The empiric relationship between excess lifetime cancer risk and airborne concentration of PCM fibers established by USEPA is expressed as follows:

$$\text{Excess Risk} = C_{air}\ (\text{PCM structures/cc}) \cdot 0.23\ (\text{per PCM/cc})$$

For example, if an individual were exposed to an airborne concentration of 0.001 PCM fibers/cc for a lifetime, the risk of developing cancer because of that exposure would be about 0.00023 (2.3E-04).

Although the PCM-based risk model remains the current standard for estimating cancer risk from asbestos (IRIS 2003), there are some technical issues associated with the approach. First, PCM has a poor ability to distinguish asbestos structures from non-asbestos structures. This is unlikely to have been a major problem in most workplace studies (where most of the airborne particles would likely have been asbestos), but may be a problem in the residential setting (where many PCM structures may not be asbestos) (Weis 2001b). Second, most researchers believe that risk of cancer from inhalation of asbestos depends on the size (length and width) and type (chrysotile, amphibole) of the asbestos, although the exact relationship is not yet clear. Thus, the empiric risk factor based on studies in the workplace may not be appropriate for use at a location (e.g., Libby) if the particle size distribution pattern of asbestos fibers in Libby were substantially different than in the workplace studies.

Because of these issues, some researchers are working to develop new methods for predicting cancer risk from inhalation of asbestos. One of these efforts is being sponsored by the USEPA and is being performed by Berman and Crump (USEPA 1999). The method being developed by Berman and Crump explicitly takes mineral class (chrysotile, amphibole) and particle size (length, width) into account. Based on work completed to date, Berman and Crump have concluded that the concentration of long (>10 um) and thin (< 0.5 um) fibers is the primary determinant of cancer risk, with a smaller contribution from intermediate length (5-10 um) thin fibers. Because thin fibers may be difficult to measure by PCM, the Berman Crump approach uses a more powerful technique (transmission electron microscopy, or TEM) as the preferred measurement technique. For convenience, structures observed in TEM that are longer than 10 um and thinner than 0.5 um are referred to as "Berman-Crump protocol structures-long" (BCPS-l), and structures observed in TEM that are 5-10 um long and thinner than 0.5 um are referred to as "Berman-Crump protocol structures-short" (BCPS-s). For lifetime exposure, the cancer risk factors for short and long protocol structure are shown below:

$$\text{Risk} = C_{air}(\text{BCPS-s})\cdot 0.049 + C_{air}(\text{BCPS-l})\cdot 15$$

3.2 Methods for Estimating PCM and BCPS Concentrations in Air

In order to estimate health risk from asbestos concentrations in air, estimates of airborne asbestos levels must have units of concentration that are consistent with the risk model selected for use (i.e., PCM fibers for the IRIS risk model, and BCPS for the Berman Crump risk model). Most samples of air analyzed at the Libby site have been analyzed using TEM and a set of counting rules specified in ISO-10312. In addition, a large number of samples have also been analyzed by TEM using a set of counting rules specified by AHERA. In both cases, all LA structures longer than about 0.5 um and having an aspect ratio greater than about 3:1 have been recorded so that the raw data are available to characterize the complete particle size distribution in air and dust samples.

For ISO 10312, data are available for over 6200 individual structures[1]. The distributions of length, width and aspect ratio are shown in Figure 3-1. The availability of these data makes it possible to calculate the fraction of all LA ISO structures[2] that fall into any particular size class, including the risk-based classes above. Note that a structure identified by TEM that has the same size attributes as required for PCM is referred to as a PCM-equivalent (PCME) structure. Based on these data, the following fractions are observed:

$$\text{PCME} = 0.28 \cdot (\text{Total ISO})$$
$$\text{BCPS-s} = 0.13 \cdot (\text{Total ISO})$$
$$\text{BCPS-l} = 0.042 \cdot (\text{Total ISO})$$

Similarly, for particles counted using AHERA rules[3], the conversion factors for estimating risk-based structures from total AHERA-based counts are as follows:

$$\text{PCME} = 0.43 \cdot (\text{Total AHERA})$$
$$\text{BCPS-s} = 0.15 \cdot (\text{Total AHERA})$$
$$\text{BCPS-l} = 0.059 \cdot (\text{Total AHERA})$$

Note: The ratios shown above may change when the AHERA database is updated and corrected

[1] See Attachment 1 for a detailed description of the data selection and calculation procedure.

[2] This includes not only the particle size classes traditionally included under ISO counting rules, but also "excluded" fibers that have been included for purposes of more fully characterizing the particle size distribution.

[3] This ratio is based only on fibers that meet AHERA counting rules, not including any 'excluded" fibers that have been recorded in the database.

Because these factors are known with good confidence, it is possible to estimate the concentration or count of a particular risk-based structure type by measuring the total number of structures and multiplying by the appropriate fraction. The advantage of estimating the concentration of risk-based structures by this approach is increased statistical confidence and decreased cost. For example, on average, only about 4% of all ISO structures are BCPS-l. Thus, to get a reliable count of the number of BCPS-l structures in a sample, it would be necessary to count at least 100-200 total structures (a slow and costly requirement). Alternatively, if the estimate of concentration is based on total structures, then a reliable estimate can be obtained by counting only 5-10 total structures and multiplying by the factor above. Because of the advantages in statistical confidence and cost savings, this is the approach that EPA has selected for use in assessing risks from various source materials at this site.

Figure 3-2 shows the relationship between PCME fibers actually observed in individual samples of air and dust and the value calculated from the total ISO count using the ratio described above. As expected, observed values may be either higher or lower than the calculated value, but the overall correlation is good.

3.3 Calculation of Risk-Based Concentrations in Air

Long-Term Exposures

Based on the risk models described above, the concentrations of Libby amphibole in air that correspond to various levels of lifetime excess cancer risk are as follows:

Risk-Based Concentration of Libby Amphibole Fibers in Air (s/cc)

Excess Risk Level	Based on IRIS Risk Model			Based on Berman-Crump Risk Model			
	PCM/ PCME	Total ISO	Total AHERA	BCPS-s	BCPS-l	Total ISO	Total AHERA
1E-02	4.3E-02	1.6E-01	1.0E-01	2.0E-01	6.6E-04	1.6E-02	1.1E-02
1E-03	4.3E-03	1.6E-02	1.0E-02	2.0E-02	6.6E-05	1.6E-03	1.1E-03
1E-04	4.3E-04	1.6E-03	1.0E-03	2.0E-03	6.6E-06	1.6E-04	1.1E-04
1E-05	4.3E-05	1.6E-04	1.0E-04	2.0E-04	6.6E-07	1.6E-05	1.1E-05

For example, if measurements in a person's home indicated that the long-term average concentration of total LA AHERA structures was 0.0010 (1.0E-03) s/cc, this would correspond to an excess lifetime cancer risk of about 1 in 10,000 (1E-04) based on the IRIS PCME risk model, and a risk of about 1 in 1,000 (1E-03) based on the Berman-Crump risk model. In both cases, it is important to note that the risks are based on an assumed long-term (70-year lifetime) exposure. If exposure is for shorter times, risks are also lower, as discussed below.

Intermediate and Short-Term Exposures

When intermediate or short-term exposures occur, the exact magnitude of the risks depends on the duration of exposure as well as the age at exposure. However, as an initial approximation, risk from less-than-lifetime exposure may be estimated by assuming risk is a linear function the time-weighted average exposure concentration. For example, the risks to a person exposed for 40 years would be about 40/70 (60%) as large as the risks to a person who was exposed for a lifetime (70 years). Likewise, an exposure that occurs only for 1 hour per day is about 1/24 = 4% as hazardous as if the exposure occurred for a full day, and an exposure that occurs only 10 days per year is about 10/365 = 2% as hazardous as if the exposure occurred every day per year. Because of this, risks from brief and intermittent exposures (e.g., those that may be encountered by firefighters at a burning house with vermiculite insulation, or those that might be experienced by a homeowner during once-only remodeling in an area with vermiculite insulation) are generally of lower concern than long-term exposures, even if the short-term exposures are to levels that would be of great concern if the exposure were long-lasting.

3.4 Risk Estimates for Indoor Air Concentrations Observed in Libby

"Typical" Indoor Air Levels

Measurements of Libby amphibole concentrations in indoor air have been performed at a number of residential and commercial properties in Libby. Based on current data, LA fibers have been detected in one or more air samples from about 40% of the locations tested. The following table summarizes the range of values observed[4], and the excess cancer risk levels that would be associated with residential exposure to the levels that have been detected.

[4] See Attachment 1 for a detailed description of the data selection and calculation procedure.

Risks from Indoor Air in Libby

Parameter	Low Detect (5th percentile)	Average Detect (mean)	High Detect (95th Percentile)
Concentration (Total ISO s/cc)	0.00014	0.0080	0.0538
Risk (IRIS model) - 40 years exposure	5E-06	3E-04	2E-03
Risk (IRIS model) - 70 years exposure	9E-06	5E-04	3E-03
Risk (Berman-Crump model) - 40 years exposure	5E-05	3E-03	2E-02
Risk (Berman-Crump model) - 70 years exposure	9E-05	5E-03	3E-02

As seen, in some cases the levels of LA detected are so low that there is little basis for concern. However, both average and high-end values are above the risk level of 1E-04 where EPA typically takes action under Superfund.

Comparing the risk estimates above with those that have been presented previously (Weis 2002a, 2002b) is difficult, since there have been a number of changes in the database as well as a change in the method used to estimate the concentration of risk-based structures (see Section 3.2, above). Nevertheless, the range of estimated PCME concentrations used to estimate risks above are generally quite similar to those used previously, as shown below.

Evaluation	Number	PCME Concentration (Detects Only) (s/cc)		
		Low	Average	High
Previous (Weis 2001b, as corrected in SRC 2002)	39 samples	0.0003	0.0017	0.0120
This report	165 properties (property average)	0.00004	0.0022	0.0150

Risks from Exposures to Disturbed Vermiculite Insulation

EPA is currently taking actions to eliminate or reduce the potential for exposure of residents and workers to vermiculite insulation. As discussed in previous memos (Weis 2002a, 2002b), vermiculite insulation is of concern because it contains LA, and disturbance of the insulation can lead to locally high concentrations of LA in air. As described above, the risks from such exposures are related both to the concentrations of LA fibers in air which may be generated, and also to the frequency and duration of such exposures. Presented below are screening-level risk estimates for two populations of people who may have this type of exposure, including residents in houses with vermiculite insulation who may be exposed periodically, and tradespeople (e.g., electricians, plumbers, other contractors) whose profession may bring them into contact with vermiculite insulation on a regular basis. All calculations are based on an assumed air concentration of 0.68 total ISO structures per cc (the mean value measured in person air monitors during active disturbance of vermiculite insulation at three homes studied during the Phase II Scenario 3 studies performed by EPA in Libby)[5]. This total ISO concentration corresponds to about 0.19 PCME s/cc, 0.089 BCPS-s s/cc and 0.028 BCPS-l s/cc.

Exposed Population	Assumed Exposure Scenario				Estimated Excess Risk of Cancer	
	Description	hrs/day	days/ yr	yrs	IRIS Risk Model	B-C Risk Model
Resident	Getting holiday decorations out of storage	0.5	2	40	3E-06	3E-05
	Once-only do-it-yourself home remodeling project	4	10	1	3E-06	3E-05
	Multiple do-it-yourself home remodeling projects	4	20	10	6E-05	6E-04
Trades person	Remodeling or repair work in homes with vermiculite insulation	8	150	25	2E-03	2E-02

As seen, infrequent exposures (such as going into an attic with exposed vermiculite only a few times per year, or a once-only remodeling project that leads to direct exposure to disturbed vermiculite) have estimated risks that do not exceed EPA's usual level of concern (1E-04). However, risks may enter a range of concern for residents who frequently engage in activities that bring them into direct exposure to vermiculite, or for tradespeople who frequently work in houses with vermiculite insulation

3.5 Risk Estimate for EPA's Air Clearance Criterion

[5] See Attachment 1 for a detailed description of the data selection and calculation procedure.

At present, EPA uses a concentration of 0.001 AHERA structures/cc in air as the criterion for determining that remedial activities in a home have been successful. If this concentration were assumed to be an accurate measure of the long-term average air concentration in a home, risks to a resident would be about 1E-04 based on the IRIS risk model, and about 9E-04 based on the Berman-Crump risk model. Risks to a tradesman working in a house remediated to this level would be about 2E-06 to 2E-05. However, these risks are very likely to be conservative (too high), since the air samples used to evaluate the clearance criterion are collected immediately after vigorous disturbance of dust with a leaf-blower. That is, the true long-term average concentration is likely to be much lower, and hence the true risks would also be much lower. Thus, application of this clearance criterion is considered to be highly protective of human health, both for residents and for tradespeople.

4.0 RISKS FROM ASBESTOS FIBERS IN DUST

4.1 Basic Equations

As noted earlier, asbestos fibers in dust are of potential health concern primarily because they can become resuspended in air, leading to the potential for inhalation exposure. The relationship between the concentration of fibers in air (s/cc) and the asbestos loading in dust (s/cm^2) may be expressed as a ratio:

$$K = C(\text{air}) / L(\text{dust})$$

Clearly, the value of K is expected to be highly variable, depending on the nature of the forces that disturb the dust and cause the resuspension. Thus, it is appropriate to consider that there are a series of K values, depending on the forces acting on the dust, and that the average K factor for a house is the time weighted-average (TWA) of the K-factors for all of the different types of activities that disturb the dust:

$$K(\text{average}) = \sum K_i \cdot TWF_i$$

where:

K_i = K factor for activity type "i"
TWF_i = Time-weighting factor for activity type "i"

For the purposes of this screening assessment, two basic types of K factors are identified for a residential setting:

- the "baseline" value that applies under routine household conditions. The forces that lead to dust resuspension include thermal air currents, mechanical vibrations, and human or pet movements and activities.

- The "active cleaning" value that applies when dust is being actively disturbed by an activity such as sweeping, dusting, beating carpets or upholstery, etc.

Thus, the average value of C(air) is calculated from L(dust) as

$$\text{Average C(air)} = \text{L(dust)} \cdot (K_{baseline} \cdot TWA_{baseline} + K_{cleaning} \cdot TWA_{cleaning})$$

Given the estimate of average C(air), risks may be estimated using the various risk models above.

4.2 Parameter Values

TWA Values

The time weighting factors for "baseline" and "cleaning" activities are expected to vary widely between different homes and different people. Based on surveys of human activity patterns reported in EPA's Exposure Factors Handbook (USEPA 1977), an average of about 2 hours per day are spent in cleaning activities (Table 15-71 and Table 15-90), and this activity occurs an average of about twice per week (Table 15-51). Based on this, the TWA for cleaning is:

$$TWF_{cleaning} = (2 \text{ hrs}/24 \text{ hrs}) / (2 \text{ days}/7 \text{ days}) = 0.024$$

Defining "baseline" as all time other than that spent in active cleaning, the TWF for baseline is:

$$TWF_{baseline} = 1 - TWF_{cleaning} = 0.976$$

K Factor for Active Cleaning

Data on resuspension factors (K factors) for dust resuspension due to various types of activities are limited, and values range widely. Values published in the literature from studies at other sites are summarized in Table 4-1 (Millette and Hayes 1994). As seen in the lower half of Table 4-1, K factors for resuspension of asbestos under controlled conditions tend to fall mainly in the range of 1E-04 to 1E-06 s/cc per s/cm^2. After excluding the values associated with operating a forklift and a cable pull (these are not representative of exposures that would occur in a home), the geometric mean value of the remaining values is about 2E-05 s/cc per s/cm^2. In this regard, the maximum possible value for the K factor is 4.1E-03, which represents the case when 100% of the dust is resuspended in the air of a room that is 8 feet high. Thus, a K factor of 2E-05 represents a case where only 0.5% of the total dust is suspended in air.

Data collected by EPA at the site during Phase II Scenario 2 were intended to provide a basis for deriving a site-specific K factor for active cleaning, but the results are disappointing. In these studies, samples of air and dust were collected in several homes during various types of active cleaning activities (sweeping, vacuuming, etc). Although the ratio of the average concentration in personal air samples (total ISO s/cc) divided by the average loading in dust (total ISO s/cm2) is 1.8E-05 s/cc per s/cm^2 (similar to the value derived from the literature)[6], there were no instances in which structures were detected in both air and dust at the same home. This prevents a meaningful analysis of the relationship in paired samples (as would be preferred). This result is partly a consequence of the statistical uncertainty around each measurement, as well as the inherent variability between different homes and different types of cleaning activities. Because of the extreme variability and uncertainty in these site-specific data, these limited site-specific data are considered to be consistent with but not preferable to the literature-based estimates for active cleaning.

K Factor for "Baseline" Activities

No data were located in the literature on the K factor that describes the resuspension of dust and asbestos particles during baseline (non-active cleaning) activities in a home or workplace, although Lumley et al. (1971) reported that the concentration of PCM fibers in air of an asbestos-insulated warehouse increased about 10-fold over baseline ("hardly any activity") when there was "a lot of activity", and that moving boxes in another warehouse increase airborne levels about 3-fold compared to baseline (no activity). Based on these data, it may be concluded that the K-factor for baseline is probably about 1/3 to 1/10 that of active disturbance. Based on the screening-level K value of 2E-05

[6] See Attachment 1 for a detailed description of the data selection and calculation procedure.

s/cc per s/cm^2 for active cleaning activities identified above, this would correspond to a baseline K-factor value of about 2E-06 to 7E-06 s/cc per s/cm^2.

An alternative value can be estimated from data collected in Libby during Phase I and Phase II studies. These studies provide data on the concentration of asbestos in indoor air (both personal and stationary monitors) and in dust in residential and commercial locations. Two approaches are possible. In the first approach, the baseline K-factor can be estimated simply by dividing the average indoor air concentration by the average indoor asbestos loading in dust[7]. The results are shown below:

Estimated K Factors for Baseline Activities in Libby

Data Collection Phase	Detection Freq.		Mean C(air) (Total ISO s/cc)	Mean L(dust) (Total ISO s/cm^2)	Ratio (Baseline K Factor)
	Air	Dust			
Phase I	60/157	198/490	0.0029	872	3.3E-06
Phase II	7/16	3/14	0.0015	213	7.2E-06

As above, because these estimates of concentrations in air and loading in dust are not paired (i.e., air and dust were not collected at the same time or place), the K-values should be interpreted only as an estimate of what may be typical under baseline conditions.

The second approach is to utilize only those data that are paired in space (i.e., both air and dust are from the same house), and to calculate the best fit line of the following form: $C(air) = K \cdot L(dust)$. A total of 151 such data points exist. Based on these data[8], the best fit linear regression has a slope of 1.3E-06 s/cc per s/cm^2. However, most of the data points (131 out of 151) are non-detect either for air and/or for dust, so the slope estimate is highly uncertain.

Based on these very limited data, it is concluded that the value for the value of K under baseline conditions likely falls in the range of 1E-06 to 8E-06 s/cc per s/cm^2, and a value of 4E-06 s/cc per s/cm^2 was selected to be representative. Clearly, this value should be viewed as only a rough estimate,

[7] See Attachment 1 for a detailed description of the data selection and calculation procedure.

[8] See Attachment 1 for a detailed description of the data selection and calculation procedure.

and it should be understood that actual values could vary substantially from home to home and from time to time.

4.3 Calculation of Risk-Based Loadings for Dust

Based on the equations and inputs discussed above, the relationship between lifetime excess cancer risk and the level of asbestos structures in dust are as follows:

Risk-Based Loading in Dust (s/cm^2)

Risk Level	Based on IRIS Risk Model			Based on Berman-Crump Risk Model			
	PCM/ PCME	Total ISO	Total AHERA	BCPS-s	BCPS-l	Total ISO	Total AHERA
1E-02	9,930	35,700	23,200	46,600	151	3,580	2,560
1E-03	993	3,570	2,320	4,660	15	358	256
1E-04	99	357	232	466	1.5	36	26
1E-05	10	36	23	47	0.15	3.6	2.6

For example, a person residing for 70 years in a home where the average dust content was 2,320 total AHERA structures per cm^2 would be expected to have an excess cancer risk of about 1E-03 based on the IRIS PCM risk model. Based on the Berman-Crump risk model, a loading of only 256 AHERA s/cm2 would correspond to a lifetime risk of 1E-03. However, it is evident from the discussions of the equations and inputs above that these risk-based values for dust should be viewed as estimates that contain a substantial amount of uncertainty. This uncertainty is due mainly to the uncertainty regarding the relationship between air and dust, as well as uncertainty in the relative contribution of different activity patterns to the average value of K. Thus, actual RBC values may be either higher or lower, depending on the actual range of conditions that exist across the community of Libby.

4.4 Risk Estimates for Dust Levels Observed in Libby

Measurements of Libby amphibole concentrations in indoor dust have been performed at a number of residential and commercial properties in Libby. Of these, LA fibers have been detected in indoor dust in about 40% of the locations (199/491). The following table summarizes the range of values observed[9], and the excess cancer risk levels that would be associated with lifetime residential exposure to the levels that have been detected.

Risks from Indoor Dust in Libby

Parameter	Low Detect (5th percentile)	Average Detect (mean)	High Detect (95th Percentile)
Concentration (Total ISO s/cm^2)	29	2,147	7,823
Risk (IRIS model)	8E-06	6E-04	2E-03
Risk (Berman-Crump model)	8E-05	6E-03	2E-02

As seen, in some cases the levels of LA detected in dust are so low that there is little basis for concern, but both average and high-end values are above the risk level of 1E-04 where EPA typically takes action under Superfund.

4.5 Evaluation of Risk Associated with EPA's Action Level for Dust

At present, EPA takes active steps to clean dust on any floor of a home where the average loading exceeds 5,000 total AHERA structures per cm^2. It is important to recognize that this action level is not based on a consideration of the long-term acceptability of this level, since the predicted lifetime risks would be quite high (1E-03 to 1E-02, depending on which risk model is used) if it were assumed that this value was the true long-term average concentration in the home. However, actual house-wide levels are likely to be lower, since samples are collected from areas most likely to be contaminated, and decisions are based on a floor-by-floor basis rather than a house-wide average. In addition, after remediation of primary sources, it is expected that dust levels will fall over time simply as a result of normal air cycling and routine cleaning by residents. Although the rate at which levels would fall is hard to predict, based on the expectation that most homes undergo some form of cleaned at least once per week (USEPA 1997), it is considered likely that dust levels will be substantially

[9] See Attachment 1 for a detailed description of the data selection and calculation procedure.

reduced within a few months, and likely fall to approximately background in less than a year. If so, then the lifetime excess risk contributed by a starting value of 5,000 AHERA structures/cm^2 would be on the order of 100-fold lower, probably in the range of 1E-04 to 1E-05, which are within EPA's usual target risk range. On this basis, the action level of 5,000 s/cm^2 for active dust remediation is considered to be fully protective of human health both for short-term and long term exposures.

5.0 RISKS FROM ASBESTOS FIBERS IN SOIL

5.1 Basic Equations

Asbestos fibers in outdoor soil can lead to human exposure by one or more of three different pathways:

1. Resuspension from soil into outdoor air as the result of wind forces acting on exposed soil
2. Resuspension from soil into outdoor air as a result of active disturbance of the soil (e.g., working in the garden, rototilling, etc).
3. Transport of soil from outdoors into indoor dust, from which indoor activities can lead to inhalation exposure as discussed in Section 5 (above).

For erosion of asbestos from soil into outdoor air, the basic equation is:

$$C(\text{outdoor air}) = C(\text{soil}) \cdot PEF/s \cdot FPG \cdot 10^{-6}$$

where :

C(outdoor air) = concentration of asbestos structures in air (s/cc)
C(soil) = concentration of asbestos in soil (grams of asbestos per gram bulk soil)
PEF = particulate emission factor (grams of silt per m^3 of air)
s = silt content of soil (grams of silt per gram of bulk soil)
FPG = average number of asbestos fibers of per gram of asbestos
10^{-6} = conversion factor (m^3 per cc)

For transport of outdoor soil into indoor dust, the basic equation is:

$$C(\text{dust}) = ksd \cdot C(\text{soil})$$

where:

C(dust) = concentration of asbestos structures in dust (grams of asbestos per gram of dust)
ksd = fraction of indoor dust that is attributable to outdoor soil (grams soil per gram dust)
C(soil) = concentration of asbestos in soil (grams per gram)

Given an estimate of C(dust), L(dust) may be estimated as:

$$L(dust) = C(dust) / D \cdot FPG$$

where:

L(dust) = asbestos loading in dust (s/cm^2)
C(dust) = asbestos concentration in dust (grams asbestos per gram dust)
D = mass of dust per unit area (grams dust per cm^2)
FPG = Number of asbestos fibers per gram asbestos

Given L(dust), risk may be calculated as described above (see Section 4.1).

Note that this approach assumes that all asbestos that is present in soil is or may become respirable particles. This approach is an over-simplification in some cases, since some asbestos particles in soil are too large to become airborne and be inhaled. However, such large particles may become disaggregated to free fibers in the future due to weathering or mechanical forces, so the risk estimates should be considered to reflect what risks may be now (if all particles are currently fibers) or may become in the future (if some particles are currently large).

5.2 Parameter Values

TWA Values

The time that different people spend indoors and outdoors is highly variable, but the average values based on a national survey are about 1.5 hours per day outdoors, and 21 hours per day indoors (the remainder is spent in vehicles) (USEPA 1997, page 15-16). Thus, the TWF for exposure to ambient outdoor air and indoor air are approximately:

TWF(ambient outdoor air) = 1.5 hrs / 24 hr = 0.0625
TWF(indoor air) = 21 hrs / 24 hr = 0.875

The time spent engaging in outdoor activities that result in active disturbance of soil (e.g., working in the garden) is also likely to be highly variable. Based on a national survey, about 2/3 of the total respondents did not engage in gardening (USEPA 1997, Table 15-61). Of the remaining respondents, a large majority (nearly 80%) spent less that 24 hours per month gardening. Taking 12 hours per month as an estimate of what is likely to be typical for people who garden, the TWF is as follows:

TWF(disturbed outdoor air) = (12 hrs/month) / (720 hrs/month) = 0.0167

PEF Factors

The release of soil particles into outdoor air as a function of wind erosion is a complex function of the wind speed, the "roughness" of the terrain (which influences how turbulent the air flow is), the size of the exposed soil source area, and the properties of the soil (including the fraction that is covered with vegetation). Based on conservative national default values, the USEPA (1996, 2001) has calculated a default as follows:

PEF (wind erosion) = 7.4E-10 kg of soil per m^3 of air

Because the fine particles in soil are preferentially eroded in preference to the coarser soil particles, it is assumed the wind-eroded soil particles all belong to the silt fraction (< 50 um in diameter).

Mathematical models exist for calculating PEFs for various types of active disturbances of soil (plowing a field, driving a vehicle on a dirt road, etc.) (Cowherd et al. 1985), but these are all very crude models and none are likely to be particularly relevant for the types of active disturbances that may affect a resident while working in their yard. Therefore, the PEF for active soil disturbance was simply assumed to be 100 times higher than for wind erosion:

PEF(active disturbance) = 100 · PEF(wind erosion) = 7.4E-08 kg of soil per m^3 of air

As will be seen below, the overall risk from asbestos in soil is not very sensitive to this assumption, so efforts to derive a more reliable value do not appear to be warranted.

Ksd Value

Indoor dust is composed of particles derived from many different sources, and only a fraction of the total is derived from exterior soil. Studies on the relationship between arsenic and lead in soil at numerous mining sites in the Rocky Mountain west suggest that in most cases, the fraction of dust derived from soil is likely to be about 20%-40%. Thus, for the purposes of the screening calculations at this site, a value of 30% (Ksd = 0.3) is assumed. Note that this assumes that the outdoor yard soil is uniformly contaminated with asbestos. In cases where only a portion of the yard is contaminated, the total soil contribution to dust may still be 30%, but only a fraction of that will contain asbestos. Thus, the value of 30% is likely to be conservative in many cases.

FPG value

The number of fibers per gram (FPG) of any particular size category of asbestos per gram total asbestos varies widely as a function of the size distribution of the asbestos particles composing the sample. At this site, an estimate of FPG for each risk-based fiber type was derived by estimating as follows:

where:

N	=	total number of LA fibers observed in samples of air and dust from Libby
x	=	total number of fibers of type "x" observed in the total set of N fibers
w_i	=	width (um) of LA fiber "i"
l_i	=	length (um) of LA fiber i"
δ	=	density of LA fibers (3.1 grams/cc)
1E-12	=	conversion factor (cc per um^3)

Based on a total of over 8,300 structures observed at Libby, estimates of FPG for each of the three main risk-based fiber types is as follows:

Fiber Type	Estimated FPG
Total	2.9E+10
PCM/PCME	9.0E+09
BCPS-s	3.9E+09
BCPS-l	1.3E+09

Silt Fraction

The fraction of a soil sample that is composed of particles that are silt-sized or smaller varies widely from location to location. Site-specific measurements of the silt content of soils in Libby have not yet been performed. However, the U.S. Department of Agriculture Soil Survey Program database for Montana does provide some data on the silt fraction for soils collected in and around Lincoln County (USDA 2003). The fraction of silt in surface soil (depth < 25cm) ranged from 0.23 to 0.95, with a mean of 0.70. The mean value of 0.70 was used in the screening-level risk calculations for soil.

Dust Loading

The amount of dust on a surface (g/cm^2) is expected to vary widely from location to location and from time to time, depending on the types and rates of dust deposition on surfaces and on the frequency and thoroughness of cleaning. At this site, a set of 20 samples of dust were collected by vacuuming five template areas of 100 cm^2 each (total area = 500 cm^2) from carpets and floors in residential properties in Libby, and weighing the amount of dust collected. Values ranged from a minimum of non-detect (< 0.0002 mg/cm^2) to a maximum of 0.06 mg/cm^2, with a mean of about 0.01 mg/cm^2. The mean value (1E-05 g/cm^2) was used in the screening-level risk calculations for soil.

5.3 Calculation of Risk-Based Concentrations for Soil

Based on the equations and inputs discussed above, the risk-based concentrations of asbestos structures in soil (expressed as mass percent) are as follows:

Risk-Based Concentrations in Soil (mass percent)

Risk Level	Based on IRIS Risk Model	Based on Berman-Crump Risk Model

1E-02	36%	3.7%
1E-03	3.6%	0.37%
1E-04	0.36%	0.04%
1E-05	0.04%	0.004%

An interesting point to note is that most of the risk (about 86%) from asbestos in soil is attributable to the transport of the soil to indoor dust rather than the exposures which occur to asbestos in ambient or disturbed outdoor air. This is mainly because the time spent outdoor exposed to ambient air or to air near disturbed soil are quite small compared to the time spent indoors.

5.4 Risks Estimates for Soil Levels Observed in Libby

Measurements of Libby amphibole concentrations in outdoor yard soil have been performed at a number of residential and commercial properties in Libby using polarized light microscopy (PLM). Of these properties, LA fibers have been observed in one or more soil samples from about 20% of the locations (64 out of 328)[10]. In most of these cases, the levels of LA in soil have been too low to quantify (these are reported as "Trace" or "<1%"), which probably corresponds with concentrations that are mainly in the 0.1-1% range. Based on the screening-level assumptions described above, soil concentrations in this range are predicted to correspond with excess lifetime cancer risk levels of 3E-05 to 3E-04 (IRIS risk model) to 3E-04 to 3E-03 (Berman Crump risk model). In a few cases, levels of asbestos were high enough to quantify, with levels of 4% to5% having been observed. If these values were assumed to be representative of the entire yard, they would correspond to a lifetime excess cancer risk in the range of 1E-03 to 1E-02 (depending on which risk model is used).

5.5 Estimated Risks at EPA's Action Level for Soil

At present, EPA removes and replaces soils that are estimated to contain 1% or more asbestos (grams per gram). In addition, EPA removes all soils with visible vermiculite at a residence if any soil location at that residence exceeds 1% asbestos. Based on the assumptions described above, a concentration of 1% LA in soil poses an excess cancer risk of about 3E-04 based on the IRIS PCM risk model and about 3E-03 based on the Berman-Crump risk model. However, these calculations are

[10] See Attachment 1 for a detailed description of the data selection and calculation procedure.

based on several assumptions that may tend to overestimate actual hazard. Most important is the assumption that the entire yard is contaminated with asbestos, while most sites evaluated to date tend to have asbestos in only one or two parts of the yard. If the total area contaminated were only 1/10 of the yard, this would tend to reduce the amount of asbestos entering house dust from yard soil, and risk estimates might be as much as 10-fold lower. In addition, the calculations do not account for the effects of snow cover and frozen ground, both of which tend to reduce transport of soil into indoor dust. Finally, the calculations do not take actual particle size into account, and particles that are too large to be respirable are evaluated as if they have undergone degradation to individual fibers. Based on these considerations, it is concluded that an action level of 1% asbestos in soil is likely to capture areas of major concern from this medium, although the possibility for soil removal later at a lower action level has not been entirely excluded at this time.

6.0 SUMMARY AND DISCUSSION

Reliable prediction of human health risk due to asbestos in environmental media (air, dust, soil) is very difficult. This is because of uncertainty at all stages of the risk assessment process. Table 6-1 lists the main sources of uncertainty, and provides a judgement about how large and in which direction the error associated with the uncertainty might be. Inspection of this table emphasizes the many different sources of uncertainty, and how uncertain the risk estimates are (especially those associated with expected releases from soil or dust). Risk managers and the public should take these uncertainties into account when interpreting the calculations in this document.

Despite this uncertainty, the screening level calculations reported in this appendix provide a starting point for quantitative risk-based decision-making at the site. More specifically, the calculations have shown that there are numerous locations in Libby where concentrations of Libby amphibole in air, dust and/or soil are above a level of potential health concern, and indicate that the current action levels used by EPA as well as the "clearance" criteria used to declare a location to be acceptable are protective and reasonable.

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TABLE 4-1. K FACTORS REPORTED AT OTHER SITES

Contaminant	Activity	K (s/cc per s/cm^2)
^{131}I-labeled dust	Active work in confined space	4.3E-05
Beryllium	Warehouse inventory	2E-02
Alpha emitters	Walking	4.9E-04
Uranium particles	Cart movement	1.45E-04
Chrysotile dust in a warehouse	Handling contaminated materials	2.0E-03 to 4.2E-03
Microorganisms	Air jet	1.2E-03
	Moist mopping	2.0E-04
Zinc Sulfide powder	Vigorous sweeping	1.9E-04
Asbestos (controlled studies)	Gym/athletic activities	2.4E-05
	Cleaning a storage area	3.1E-05
	Operating a forklift in a warehouse	3.6E-03
	Cable pull	1.4E-05
	Broom sweeping	7.1E-05
	Conventional carpet cleaning	3.9E-06

Source: Values are compiled from numerous reports as summarized by Millette and Hayes (1994)

TABLE 6-1. SUMMARY OF UNCERTAINTIES

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
Inhalation of fibers in air	C(air)	Based on typical number of grid openings counted (10-40), estimates have moderate to high statistical uncertainty. Values may vary as a function of time and location.	Medium	Either higher or lower
	Cancer Unit Risk Factors	Dependence of cancer risk on fiber size and type of asbestos not certain; more than 10-fold difference between different models	Medium-Large	Unknown
	Non-cancer reference concentration	No value is currently available; dependence on fiber size and type is unknown	Large	Underestimate non-cancer risk
Exposure to fibers from disturbance of indoor dust	C(dust)	Based on typical number of grid openings counted (10-40), estimates have moderate to high statistical uncertainty. Values may vary as a function of time and location.	Medium	Either higher or lower
	K Factor for active cleaning	Value is highly variable, depends on details of source, disturbance, and location; values from literature span 2 orders of magnitude; site specific estimate of mean is within literature range	Large	Either higher or lower
	K Factor for "baseline" residential activities	Nearly no information from literature. Site value is crude estimate of "typical". Actual values may vary widely.	Very Large	Either higher or lower
	TWF for active cleaning and baseline exposures	Based on national default values. Activity patterns in Libby may be different.	Small	Either higher or lower

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
Exposure to asbestos in outdoor air due to releases from soil	C(soil)	Quantification of asbestos in soil is difficult; current methods are only semi-quantitative. Estimates do not account for the presence of large (non-respirable) particles, since these may become respirable in the future.	Medium	Either higher or lower
	PEF for release of asbestos from soil to ambient outdoor air	Based on conservative national default values. Conditions in Libby may be different. For example, the factor assumes 50% vegetative cover, while actual site conditions may vary. The factor does not consider effect of snow cover or frozen ground.	Small	More likely to overestimate than underestimate
	Silt content of soil	Based on county wide statistics. Conditions in Libby may differ.	Small	Either higher or lower
	TWF for exposure to ambient outdoor air	Based on national default values. Activity patterns in Libby may be different.	Small	Either higher or lower
Exposure to asbestos in outdoor air due to releases from soil	TWF for active soil disturbance	Based on national default values for gardening. Activity patterns in Libby may be different.	Small	More likely to overestimate than underestimate
	PEF for release of asbestos from soil to outdoor air following active disturbance	Assumed value, very uncertain. Nevertheless, because exposure frequency and duration are assumed to be small, overall contribution to risk is small.	Small	Unknown
Exposure to asbestos in soil following transfer to indoor dust	Transfer of asbestos from soil into indoor dust	Based on studies on lead and arsenic at other sites. Conditions in Libby may vary. Assumes that entire yard is contaminated with asbestos. If only hot-spots exist, risks will be lower. Does not quantitatively consider effect of snow, frozen ground, or vegetative cover.	Large	Either higher or lower; probably higher in most cases.

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
	Estimate of fibers per gram of asbestos	Based on site data.	Small.	Unknown.
	Dust loading	Based on limited site data. Values are highly variable between locations, and are also likely to vary with time.	Large	Either higher or lower.

ATTACHMENT 1
DOCUMENTATION OF DATABASE QUERIES AND DATA REDUCTION

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1 INTRODUCTION

This attachment provides details of methods used to obtain data from the Libby 2 Database and to calculate values and parameters needed in risk evaluation. All results are based on the database as it existed on July 31, 2003.

2 CREATING A HORIZONTAL DATABASE LAYOUT FOR TEM RESULTS

The Libby 2 Database table that contains all of the raw results data (called "BtblResults") is organized in a vertical layout (see tables below for an example of horizontal vs. vertical layout). For the purposes of running efficient queries, SRC has converted the organizational structure of the TEM structure data to a horizontal layout using a crosstab query [1].

Example of a horizontal layout:

Analysis IDSeqN	Grid Name	Primary Structure	Total Structure	Length	Width	Aspect Ratio	Class
5678	A3	1	1	5.88	0.28	21.00	LA

Example of a vertical layout:

Analysis IDSeqN	Grid Name	Characteristic	Result	Class
5678	A3	Primary Structure	1	LA
5678	A3	Total Structure	1	LA
5678	A3	Length	5.88	LA
5678	A3	Width	0.28	LA
5678	A3	Aspect Ratio	21.00	LA

3 PARTICLE SIZE DISTRIBUTIONS

3.1 ISO/AHERA Structure Distribution Figures

The Libby amphibole (LA) structure distributions shown in Figure 3-1 were generated by querying the database to obtain all LA structures reported for air and dust samples by both TEM-ISO and TEM-AHERA (N = 6238 ISO structures, N = 2116 AHERA structures). Cumulative frequency distributions were generated for length, width and aspect ratio [2].

Interim DB: TEM Calc ISO (Btbl Linkage).mdb & TEM Calc AHERA (Btbl Linkage).mdb Query Name: structure dist graph *Based on the Horizontal Layout of Raw Structure Data (see below for details)*		
Field	Constraint	Comment
SampleMediaDesc	Like "Air" Or Like "Dust"	
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)

[1] The crosstab queries (qryTEMResultsCrosstab) for ISO and AHERA are located in the interim DBs "TEM Calc ISO (Btbl Linkage).mdb" and "TEM Calc AHERA (Btbl Linkage).mdb", respectively. Because of their complexity, query details are not provided in this attachment but are available upon request.

[2] Dist graphs 7-31-03.xls

AnalysisMethod	Like "TEM-ISO10312" or Like "TEM-AHERA"	
ResultsMineralClass	Like "LA"	
TSTRUC (Total)	Is Not Null And Not Like 0	Excludes all non-countable structures

3.2 ISO/AHERA Structure Statistics

Every LA structure identified by TEM-ISO or TEM-AHERA for both air and dust (using the same structure data set used to prepare structure distribution figures above) was classified as to its size class on the basis of length, width, and aspect ratio as follows [3]:

AHERA: Length ≥ 0.5um, Aspect Ratio ≥ 5
PCME: Length ≥ 5um, Width > 0.25um, and Aspect Ratio ≥ 3
BCPS-short: Length ≥ 5um and < 10um, Width ≤0.5um
BCPS-long: Length ≥ 10um, Width ≤ 0.5um

Based on these classifications, the following ratios were established:

		Ratio
PCME/ISO	1734/6238	0.28
BCPS-s/ISO	812/6238	0.13
BCPS-l/ISO	261/6238	0.042
PCME/AHERA	872/2034	0.43
BCPS-s/AHERA	303/2034	0.15
BCPS-l/AHERA	119/2034	0.059

[3] Dist stats 7-31-03.xls

		AnalysisMethod		
		TEM-AHERA	TEM-ISO10312	Total
Air	Total Structures	2018	4401	6419
	AHERA	1945	3876	5821
	PCME	848	1388	2236
	BCPS-s	290	574	864
	BCPS-l	113	208	321
Dust	Total Structures	98	1837	1935
	AHERA	89	1728	1817
	PCME	24	346	370
	BCPS-s	13	238	251
	BCPS-l	6	53	59
Air + Dust	Total Structures	2116	6238	8354
	AHERA	2034	5604	7638
	PCME	872	1734	2606
	BCPS-s	303	812	1115
	BCPS-l	119	261	380

3.3 Fibers per Gram

The number of asbestos fibers per gram of total asbestos (FPG) was calculated as follows [4]:

FPG = # of LA Structures$_{\text{fiber type}}$ / Total LA Mass

where: fiber type = PCME, BCPS-s or BCPS-l
Total LA Mass (g) = $\sum$ length (um) $\cdot$ width^2 (um) $\cdot$ 1E-12 (cm^3/um^3) $\cdot$ 3.1 (g/cm^3)

Asbestos fibers per gram of total asbestos (FPG)			
	LA structures	LA mass (g)	FPG
total	8354	2.89E-07	2.9E+10
PCME	2606		9.0E+09
BCPS-s	1115		3.9E+09
BCPS-l	380		1.3E+09

4 CALCULATING THE AREA-EVALUATED-WEIGHTED (AEW) CONCENTRATION/LOADING VALUE

This risk evaluation focused on air concentrations and dust loadings as analyzed by TEM-ISO. For each ISO analysis, concentration/loading is reported for each of three mineral classes – Libby amphibole (LA), other amphibole (OA), and crysotile (C) – for seven structure dimension "bins". The structure dimension bins are defined as follows:

[4] Dist stats 7-31-03.xls

Bin	Length	Width	Aspect Ratio
A			< 5
B	< 0.5um		≥ 5
C		> 0.5um	≥ 5
D	≥ 0.5um - 5um	≤ 0.5um	≥ 5
E	5um - 10um	≤ 0.5um	≥ 5
F	> 10um	≤ 0.5um	≥ 5
G	all	all	all

Summary statistics for air and dust were based on concentrations/loadings from LA, Bin G.

If an air or dust sample (which is represented by a unique Index ID) was analyzed using the same Prep Method (Direct or Indirect) more than once (e.g.: one sample analyzed by ISO Indirect counting 10 grid openings (GOx) on 7/12/01 and 30 GOx on 9/2/01), it is necessary to calculate the total Area-Evaluated-Weighted (AEW) concentration/loading value across all analyses for the sample.

The AEW concentration/loading is calculated using the following steps and equations [5]:

AEW Concentration or Loading = ∑ (GOx · GO area · Concentration or Loading) / ∑ (GOx · GO area)

Step 1 – For each Analysis ID, calculate GOx · GO area · Concentration or Loading (GOxAC)
Step 2 – For each Analysis ID, calculate GOx · GO Area (GOxA)
Step 3 – For each Prep Method, calculate the ∑(GOxAC) and ∑(GOxA)
Step 4 – For each Prep Method, calculate the AEW by dividing ∑(GOxC) by ∑(GOx)
Step 5 – If an Index ID has results for both Prep Methods (Direct and Indirect), select the maximum concentration/loading value to represent the Index ID.

Example:

Index ID	Analysis ID	Media	Analysis Method	Prep Method	GOx	LA Bin G count	LA Bin G conc	AEW LA Bin G conc	Final AEW LA Bin G conc
X-00123	001	Air	ISO	Indirect	10	1	0.008	0.011	0.03
X-00123	002	Air	ISO	Indirect	30	2	0.012		

[5] The AEW calculations are performed within the interim DB "TEM Calc ISO (Btbl Linkage).mdb" in a four part query (qry_ISO LA BinG Conc). Because of its complexity, query details are not provided in this attachment but are available upon request.

Index ID	Analysis ID	Media	Analysis Method	Prep Method	GOx	LA Bin G count	LA Bin G conc	AEW LA Bin G conc	Final AEW LA Bin G conc
X-00123	003	Air	ISO	Direct	10	1	0.03	0.03	

5 INDOOR AIR CONCENTRATIONS OBSERVED IN LIBBY

5.1 Exposures to Typical Indoor Air

In order to evaluate risks from typical residential and workplace exposures to indoor air in Libby, the database was queried to obtain air concentrations for all indoor air samples (personal and stationary) collected during Phase 1, Phase 2 Scenario 1, and Phase 2 Scenario 2 (pre-activity). Air samples collected during the Phase 1R investigation were excluded because they are likely to be impacted by remedial activities and not representative of typical exposure scenarios.

Air concentrations were averaged first across all samples within a property and then summary statistics were calculated across properties [6].

Total ISO, AEW Bin G LA Concentration

Media		Detect. Freq.	Mean[1]	5th Percentile[1]	95th Percentile[1]	Mean sensitivity[2]
Indoor Air (s/cc)	by sample	107/349	0.0215	0.00021	0.1182	0.0068
Indoor Air (s/cc)	by property	65/165	0.0080	0.00014	0.0538	0.0028

1 Based on Detects only
2 Based on NDs only

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 1 air-dust data		
Field	Constraint	Comment
SamplePhaseDesc	Like "Phase 1"	
LocationLandUse Desc	Not Like "Industrial"	Excludes any industrial properties that are not representative of the risk evaluation exposure scenarios.
LocationProperty GroupDesc	Not Like "*Screen*" and Not Like "*Export*" and Not Like "2059 Bryant St (Denver, CO)"	Excludes any samples collected from the Screening Plant or Export Facility because they are not representative of the risk evaluation exposure scenarios. Excludes properties not located in Libby, MT.

6 air dust summ stats_risk calc.xls

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 1 air-dust data		
Field	Constraint	Comment
SampleMediaDesc	Like "Air" or Like "Dust"	
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)
For Air Samples,		
SampleMatrixDesc	Not Like "Outdoor"	Excludes any samples that are not representative of indoor exposures.
For Dust Samples,		
SampleMatrixDesc	Not Like "Cloth" and Not Like "Vehicle"	Excludes any samples that are not representative of indoor exposures.

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 2, scenario 1 data		
Field	Constraint	Comment
SamplePhaseDesc	Like "Phase 2"	
SampleScenarioDesc	Like "01-*"	Restricts samples to those collected during Phase 2, Scenario 1 (routine activity).
SampleMediaDesc	Like "Air"	
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)
For Air Samples,		
SampleMatrixDesc	Not Like "Outdoor"	Excludes any samples that are not representative of indoor exposures.
PumpFilterDiameter	Like 25	Excludes any Hazdust samples.

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 2, scenario 2 data		
Field	Constraint	Comment
SamplePhaseDesc	Like "Phase 2"	
SampleScenarioDesc	Like "02-*"	Restricts samples to those collected during Phase 2, Scenario 2 (cleaning).

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 2, scenario 2 data		
Field	Constraint	Comment
SampleMediaDesc	Like "Air"	
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)
For Air Samples,		
SampleMatrixDesc	Not Like "Outdoor"	Excludes any samples that are not representative of indoor exposures.
PumpFilterDiameter	Like 25	*Note: several samples designated as NULL required reclassification.* Excludes any Hazdust samples.
SampleTWAEXC	Like "TWA"	*Note: several samples required reclassification.* Restricts samples to those collected across the full period, excludes any excursion samples.
SamplePrePostClear	Like "Pre"	*Note: several samples required reclassification.* Restricts samples to those collected prior to commencement of cleaning activities.

5.2 Exposures to Disturbed Vermiculite

In order to evaluate the exposure of residents and workers to vermiculite insulation, the database was queried to obtain air concentrations for all indoor air samples (personal and stationary) collected during Phase 2 Scenario 3 (collected during active vermiculite disturbance).

Air concentrations were averaged first across all samples within a property and then summary statistics were calculated across properties [7].

Total ISO, AEW Bin G LA Concentration

Summary across properties:	
0.45	average air conc (s/cc) stationary
0.68	average air conc (s/cc) personal

[7] Phase 2, Scenario 3 Air Data.xls

Interim DB: TEM Calc ISO (Btbl Linkage).mdb Query Name: phase 2, scenario 3 data		
Field	*Constraint*	*Comment*
SamplePhaseDesc	Like "Phase 2"	
SampleScenarioDesc	Like "03-*"	Restricts samples to those collected during Phase 2, Scenario 3 (active disturbance).
SampleMediaDesc	Like "Air"	
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)
For Air Samples,		
SampleMatrixDesc	Not Like "Outdoor"	Excludes any samples that are not representative of indoor exposures.
PumpFilterDiameter	Like 25	*Note: several samples designated as NULL required reclassification.* Excludes any Hazdust samples.
SampleTWAEXC	Like "TWA"	*Note: several samples required reclassification.* Restricts samples to those collected across the full period, excludes any excursion samples.
SamplePrePostClear	Like "N/A"	*Note: "N/A" = During; several samples required reclassification.* Restricts samples to those collected during active disturbance activities.

6 DERIVATION OF RESUSPENSION (K) FACTORS

6.1 K Factor for Active Cleaning

In order to derive site-specific estimates of resuspension (K) factors associated with active cleaning, the database was queried to obtain air concentrations and dust loadings for all indoor samples collected during Phase 2 Scenario 2. The data set is nearly identical to that provided by the query "phase 2, scenario 2 data" (see Section 4) with the following exceptions:

Field	Constraint	Comment
SampleMediaDesc	Like "Air" or Like "Dust"	
For Air Samples,		

Field	Constraint	Comment
SamplePrePostClear	Like "N/A"	*Note: several samples required reclassification.* Restricts samples to those collected during active cleaning.
For Dust Samples,		
SamplePrePostClear	Like "Pre"	*Note: several samples required reclassification.* Restricts samples to those collects prior to commencement of cleaning activities.

The average Scenario 2 personal air AEW LA Bin G concentrations (non-hazdust, full period, during activity) were calculated within each property. The average Scenario 2 dust AEW LA Bin G loading (pre-activity) was calculated within each property. Non-detects were evaluated at 0. The average Scenario 2 air concentration across all properties was then divided by the average Scenario 2 dust loading across all properties [8].

Cleaning K: 3.89E-03 / 2.13E+02 ⟶ **1.8E-05**
Avg Scenario 2 Air (Personal, Full, During) / Avg Scenario 2 Dust (Pre-Activity)

6.2 K Factor for "Baseline" Activities

6.2.1 Based on Phase 2 Data

In order to derive site-specific estimates of resuspension (K) factors associated with "baseline" activities, the database was queried to obtain air concentrations and dust loadings for all indoor samples collected during Phase 2 Scenario 1 and Phase 2 Scenario 2 (pre-activity). The data sets are identical to that provided by the queries "phase 2, scenario 1 data" and "phase 2, scenario 2 data" (see Section 4).

The average Scenario 1 personal and average stationary air AEW LA Bin G concentrations (non-hazdust, full period) were calculated within each property. The average Scenario 2 dust AEW LA Bin G loading (pre-activity) was calculated within each property. Non-detects were evaluated at 0. The average Scenario 1 air concentration across all properties was then divided by the average Scenario 2 dust loading across all properties [9].

[8] site-specific K_7-31-03.xls

[9] site-specific K_7-31-03.xls

Background K: 1.53E-03 / 2.13E+02 → **7.2E-06**
Avg Scenario 1 Air (Personal+Stationary) / Avg Scenario 2 Dust (Pre-Activity)

Detection Freq.:	Air	Dust
	7/16	3/14

6.2.2 Based on Phase 1 Data

Several air and dust samples collected at residential and commercial locations as part of the Phase 1 investigation are representative of "baseline" activities, therefore the database was queried to obtain air concentrations and dust loadings for all indoor samples collected during Phase 1. The data set is identical to that provided by the query "phase 1 air-dust data" (see Section 4).

The average Phase 1 personal and average stationary air AEW LA Bin G concentrations were calculated within each property. The average Phase 1 dust AEW LA Bin G loading was calculated within each property. Non-detects were evaluated at 0. The average Phase 1 air concentration across all properties was then divided by the average Phase 1 dust loading across all properties [10].

	detect. freq.		Avg	Stdev	50th	90th	99th
air	60/157	38%	2.85E-03	1.65E-02	0.00E+00	8.59E-04	9.51E-02
dust	198/490	40%	8.72E+02	4.04E+03	0.00E+00	1.17E+03	1.82E+04
	Phase 1, Baseline K:		**3.3E-06**				

6.2.3 Based on Phase 1 and Phase 2 Data

For each property in which both air and dust were sampled, the average Phase 1 & Phase 2, Scenario 2 personal and average stationary air AEW LA Bin G concentration (non-hazdust, full period, pre-activity) was calculated within each property. The average Phase 1 & Phase 2, Scenario 2 dust AEW LA Bin G loading (pre-activity) was calculated within each property. Non-detects were evaluated at 0. The paired data for each property was plotted and a linear regression line was fit assuming a y-intercept of zero [11].

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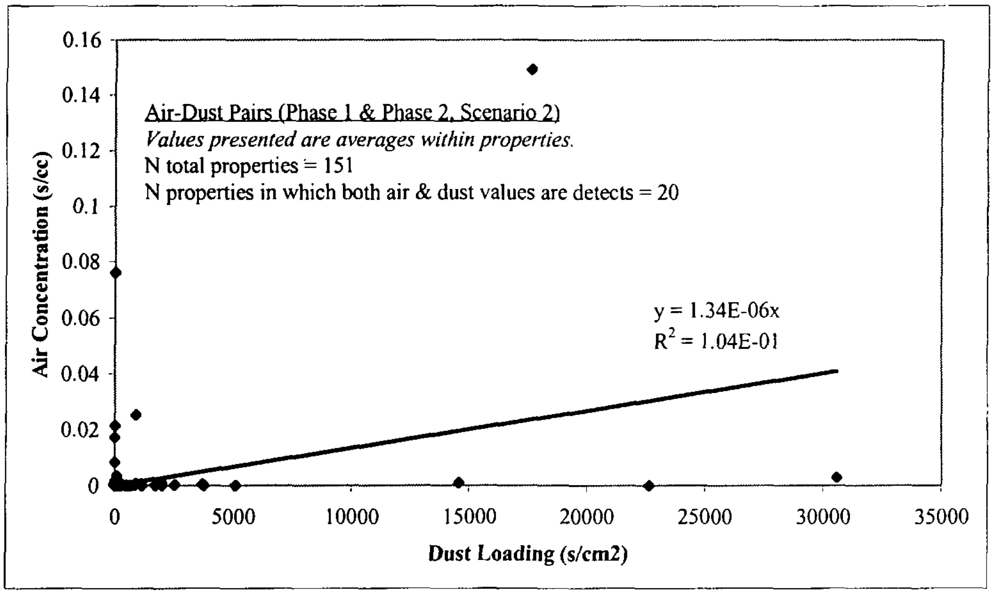
[10] ph1 air-dust.xls (TAB: all_house avg)

[11] ph1 & ph2 air-dust pairs.xls



7 DUST LEVELS OBSERVED IN LIBBY

In order to evaluate risks from typical residential and workplace exposures to indoor dust in Libby, the database was queried to obtain dust loading for all indoor dust samples collected during Phase 1 and Phase 2 Scenario 2 (pre-activity). The data sets are identical to that provided by the queries "phase 2, scenario 1 data" and "phase 2, scenario 2 data" (see Section 4). Dust samples collected during the Phase 1R investigation were excluded because they are likely to be impacted by remedial activities and not representative of typical exposure scenarios.

Dust loadings were averaged first across all samples within a property and then summary statistics were calculated across properties [12].

Total ISO, AEW Bin G LA Loading

Media	Detect. Freq.	Mean[1]	5th Percentile[1]	95th Percentile[1]	Mean sensitivity[2]
Indoor Dust (s/cm2)	199/491	2,147	29	7,823	1,292

1 Based on Detects only

2 Based on NDs only

8 SOIL LEVELS OBSERVED IN LIBBY

In order to evaluate risks from typical residential exposures to surface soil in Libby, the database was queried to obtain asbestos mass fraction estimates for all soil samples collected during the

[12] air dust summ stats_risk calc.xls

Contaminant Screening Study. Results were restricted to analyses performed by PLM-NIOSH 9002, PLM-Gravimetric, or PLM-Visual Estimation.

Interim DB: Non ISO-AHERA DB (Btbl Linkage).mdb
Query Name: soil data_PLM-VE

Field	Constraint	Comment
SamplePhaseDesc	Like "Contaminant Screening Study"	
LocationProperty GroupDesc	Not Like "Screening Plant"	Excludes any samples collected from the Screening Plant because they are not representative of typical residential exposure scenarios.
SampleMediaDesc	Like "Soil-Like"	
SampleMatrixDesc	Like "Surface Soil"	Excludes soils collected from subsurface depths because residential contact is unlikely.
SampleQCTypeDesc	Like "Field Sample"	Excludes all QC samples (e.g. blanks, etc.)
AnalysisMethod	Like "PLM-VE"	
AnalysisLabQCDesc	Like "Not a QA*"	Excludes all QA samples (e.g. Recounts, etc.)
ResultsMineralClass	Like "LA"	

Interim DB: Non ISO-AHERA DB (Btbl Linkage).mdb
Query Name: soil data_PLM-Grav

Identical to "soil data_PLM-VE" with the following exceptions:

Field	Constraint	Comment
AnalysisMethod	Like "PLM-Grav"	

Interim DB: Non ISO-AHERA DB (Btbl Linkage).mdb
Query Name: soil data_PLM-9002

Identical to "soil data_PLM-VE" with the following exceptions:

Field	Constraint	Comment
AnalysisMethod	Like "PLM-9002"	
ResultsMineralClass	Like "TREM-ACTN"	This mineral class is representative of "LA".

In cases where more than one analysis was performed for the same sample, the highest analysis result was used to represent the sample [13]. In cases where more than one sample was collected for the same property, the highest sample result was used to represent the property. The following ranking system was used to select the highest result:

Detected >> **below QL** >> **Trace** >> **Not Detected**

328	N Properties w/ 1+ soil samples analyzed via PLM		
	264	ND	*80%*
	46	Tr	*14%*
	14	<QL	*4%*
	4	Detect	*1%*

For soil samples in which both the coarse and fine fractions were analyzed and one or both of the result values were detects, the final sample result was the mass-weighted average of the two fractions [14]. The mass-weighted average was calculated as:

$$(MF\%_{coarse} \cdot Mass_{coarse} + MF\%_{fine} \cdot Mass_{fine}) / (Mass_{coarse} + Mass_{fine})$$

[13] soil summ stats_risk calc.xls

[14] soil summ stats_risk calc.xls

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APPENDIX 1

SCREENING LEVEL ESTIMATES OF EXPOSURE AND RISK FROM LIBBY AMPHIBOLE IN AIR, DUST, AND SOIL

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APPENDIX 1

SCREENING LEVEL ESTIMATES OF EXPOSURE AND RISK FROM LIBBY AMPHIBOLE IN AIR, DUST, AND SOIL

NOTE: All numeric values derived from the database are DRAFT and are subject to revision pending changes in the database or revision of data selection procedures.

1.0 INTRODUCTION

This appendix is a description of the methods used by EPA to perform a screening-level evaluation of the potential risks of cancer to residents in Libby, MT, from inhalation exposures to amphibole asbestos fibers in air. For convenience, amphibole fibers of this type are referred to as Libby Amphiboles (LA). At present, quantitative methods are not available for estimating the level of non-cancer risks from asbestos exposures.

The methods used in this appendix to evaluate risks from asbestos in air are the same as those that have been used previously (Weis 2000, 2001a, 2001b), but take advantage of new information on concentration and particle size distribution derived from site-specific studies. In addition, the methods used here begin to assess the relationship between asbestos concentrations in various source media (indoor dust, outdoor soil) and resultant health risk to residents. The purpose of this evaluation is to provide risk managers with a frame of reference for judging the magnitude of cancer risk associated with varying levels of contamination in these source materials, and to support the establishment of cleanup triggers for the on-going residential/commercial cleanup in Libby.

2.0 BASIC APPROACH

Risk from asbestos is associated mainly with inhalation exposure of suspended asbestos fibers. Because asbestos fibers are heavier than air, they do not occur in air unless they have been released from some type of source material by a disturbance:

Source -----> Air ------> Inhalation Exposure ----> Increased Cancer Risk

The concentration of fibers that occur in air following disturbance of a source and the resultant level of human exposure and risk depend on a very wide variety of highly variable factors, including:

- the concentration of fibers in the source material
- the nature of the disturbance of the source
- the physical properties of the source
- the volume of air into which the fibers are released
- the air flow or ventilation rate in the area where fibers are released
- the particle size distribution of the released fibers
- the frequency and duration of the release
- the frequency and duration of human exposure in the area where release has occurred

Because of these many factors and the wide range of values that each may assume, the ability to predict risk to a resident based only on a measure of the concentration of fibers in the source material is very limited. Conversely, the ability to specify a concentration of fibers in the source material that is "safe" is also very difficult. Nevertheless, if reasonable estimates are made for all of these variables, it is possible to derive a screening-level estimate of the "safe" concentration of asbestos in source materials. While uncertain, such an estimate does provide a useful frame of reference that may be helpful to risk managers faced with the responsibility for deciding which sources require remediation.

3.0 RISKS FROM ASBESTOS FIBERS IN AIR

3.1 Inhalation Risk Models

Information on the quantitative relationship between inhalation exposure to asbestos and increased risk of cancer (mesothelioma and/or lung cancer) are based mainly on studies of workers who have been exposed to various types and levels of asbestos in the workplace. Most of these studies estimated the concentration of asbestos in air using phase contrast microscopy (PCM). In order to be counted as a PCM structure, a particle must have an aspect ratio (length divided by width) of at least 3:1, must have a length of 5 um or more, and must be thick enough to be detectable under PCM (about 0.25 um or more). The empiric relationship between excess lifetime cancer risk and airborne concentration of PCM fibers established by USEPA is expressed as follows:

$$\text{Excess Risk} = C_{air}\ (\text{PCM structures/cc}) \cdot 0.23\ (\text{per PCM/cc})$$

For example, if an individual were exposed to an airborne concentration of 0.001 PCM fibers/cc for a lifetime, the risk of developing cancer because of that exposure would be about 0.00023 (2.3E-04).

Although this risk model remains the current standard for estimating cancer risk from asbestos (IRIS 2003), there are some technical issues associated with the approach. First, PCM has a poor ability to distinguish asbestos structures from non-asbestos structures. This is unlikely to have been a major problem in most workplace studies (where most of the airborne particles would likely have been asbestos), but may be a problem in the residential setting (where many PCM structures may not be asbestos) (Weis 2001b). Second, most researchers believe that risk of cancer from inhalation of asbestos depends on the size (length and width) and type (chrysotile, amphibole) of the asbestos, although the exact relationship is not yet clear. Thus, the empiric risk factor based on studies in the workplace may not be appropriate for use at a location (e.g., Libby) if the particle size distribution pattern of asbestos fibers in Libby were substantially different than in the workplace studies.

Because of these issues, some researchers are working to develop new methods for predicting cancer risk from inhalation of asbestos. One of these efforts is being sponsored by the USEPA and is being performed by Berman and Crump (USEPA 1999). The method being developed by Berman and Crump explicitly takes mineral class (chrysotile, amphibole) and particle size (length, width) into account. Based on work completed to date, Berman and Crump have concluded that the concentration of long (>10 um) and thin (< 0.5 um) fibers is the primary determinant of cancer risk, with a smaller contribution from intermediate length (5-10 um) thin fibers. Because thin fibers may be difficult to measure by PCM, the Berman Crump approach uses a more powerful technique (transmission electron microscopy, or TEM) as the preferred measurement technique. For convenience, structures observed in TEM that are longer than 10 um and thinner than 0.5 um are referred to as "Berman-Crump protocol structures-long" (BCPS-l), and structures observed in TEM that are 5-10 um long and thinner than 0.5 um are referred to as "Berman-Crump protocol structures-short" (BCPS-s). For lifetime exposure, the cancer risk factors for short and long protocol structure are shown below:

$$\text{Risk} = C_{air}(\text{BCPS-s})\cdot 0.049 + C_{air}(\text{BCPS-l})\cdot 15$$

3.2 Methods for Estimating PCM and BCPS Concentrations in Air

In order to estimate health risk from asbestos concentrations in air, estimates of airborne asbestos levels must have units of concentration that are consistent with the risk model selected for use (i.e., PCM fibers for the IRIS risk model, and BCPS for the Berman Crump risk model). Most samples of air analyzed at the Libby site have been analyzed using TEM and a set of counting rules specified in ISO-10312. In addition, a large number of samples have also been analyzed by TEM using a set of counting rules specified by AHERA. In both cases, all LA structures longer than about 0.5 um and having an aspect ratio greater than about 3:1 have been recorded so that the raw data are available to characterize the complete particle size distribution in air and dust samples.

For ISO 10312, data are available for over 6200 individual structures[1]. The distributions of length, width and aspect ratio are shown in Figure 3-1. The availability of these data makes it possible to calculate the fraction of all LA ISO structures[2] that fall into any particular size class, including the risk-based classes above. Note that a structure identified by TEM that has the same size attributes as required for PCM is referred to as a PCM-equivalent (PCME) structure. Based on these data, the following fractions are observed:

$$\text{PCME} = 0.28\cdot(\text{Total ISO})$$
$$\text{BCPS-s} = 0.13\cdot(\text{Total ISO})$$
$$\text{BCPS-l} = 0.042\cdot(\text{Total ISO})$$

Similarly, for particles counted using AHERA rules[3], the conversion factors for estimating risk-based structures from total AHERA-based counts are as follows:

$$\text{PCME} = 0.43\cdot(\text{Total AHERA})$$
$$\text{BCPS-s} = 0.15\cdot(\text{Total AHERA})$$
$$\text{BCPS-l} = 0.059\cdot(\text{Total AHERA})$$

Note: The ratios shown above may change when the AHERA database is updated and corrected

[1] See Attachment 1 for a detailed description of the data selection and calculation procedure.

[2] This includes not only the particle size classes traditionally included under ISO counting rules, but also "excluded" fibers that have been included for purposes of more fully characterizing the particle size distribution.

[3] This ratio is based only on fibers that meet AHERA counting rules, not including any 'excluded" fibers that have been recorded in the database.

Because these factors are known with good confidence, it is possible to estimate the concentration or count of a particular risk-based structure type by measuring the total number of structures and multiplying by the appropriate fraction. The advantage of estimating the concentration of risk-based structures by this approach is increased statistical confidence and decreased cost. For example, on average, only about 4% of all ISO structures are BCPS-l. Thus, to get a reliable count of the number of BCPS-l structures in a sample, it would be necessary to count at least 100-200 total structures (a slow and costly requirement). Alternatively, if the estimate of concentration is based on total structures, then a reliable estimate can be obtained by counting only 5-10 total structures and multiplying by the factor above. Because of the advantages in statistical confidence and cost savings, this is the approach that EPA has selected for use in assessing risks from various source materials at this site.

Figure 3-2 shows the relationship between PCME fibers actually observed in individual samples of air and dust and the value calculated from the total ISO count using the ratio described above. As expected, observed values may be either higher or lower than the calculated value, but the overall correlation is good.

3.3 Calculation of Risk-Based Concentrations in Air

Long-Term Exposures

Based on the risk models described above, the concentrations of Libby amphibole in air that correspond to various levels of lifetime excess cancer risk are as follows:

Risk-Based Concentration of Libby Amphibole Fibers in Air (s/cc)

Excess Risk Level	Based on IRIS Risk Model			Based on Berman-Crump Risk Model			
	PCM/ PCME	Total ISO	Total AHERA	BCPS-s	BCPS-l	Total ISO	Total AHERA
1E-02	4.3E-02	1.6E-01	1.0E-01	2.0E-01	6.6E-04	1.6E-02	1.1E-02
1E-03	4.3E-03	1.6E-02	1.0E-02	2.0E-02	6.6E-05	1.6E-03	1.1E-03
1E-04	4.3E-04	1.6E-03	1.0E-03	2.0E-03	6.6E-06	1.6E-04	1.1E-04
1E-05	4.3E-05	1.6E-04	1.0E-04	2.0E-04	6.6E-07	1.6E-05	1.1E-05

For example, if measurements in a person's home indicated that the long-term average concentration of total LA AHERA structures was 0.0010 (1.0E-03) s/cc, this would correspond to an excess lifetime cancer risk of about 1 in 10,000 (1E-04) based on the IRIS PCME risk model, and a risk of about 1 in 1,000 (1E-03) based on the Berman-Crump risk model. In both cases, it is important to note that the risks are based on an assumed long-term (lifetime) exposure. If exposure is for shorter times, risks are also lower, as discussed below.

Short-term Exposures

When short-term exposures occur, the magnitude of the risks depends on the duration and level of exposure as well as the age at exposure. However, as an initial approximation, risk from short-term exposure may be estimated by assuming that risk is a linear function the time-weighted average exposure concentration. For example, assume that a certain type of activity results in exposure to 0.1 PCM structure/cc. If this exposure were to occur continuously for a lifetime, the risk of cancer would be very high (about 2 in 100, or 2E-02). However, if the exposure were to occur only for 1 hour per day, the risk would be reduced by a factor of 1/24 (24-fold). Likewise, if exposure were to occur only 10 days per year, risk would be reduced by a factor of 10/365 (36.5-fold). Because of this, risks from brief and intermittent exposures (e.g., those that may be encountered by firefighters at a burning house with vermiculite insulation, or those that might be experienced by a homeowner during once-only remodeling in an area with vermiculite insulation) are generally of lower concern than long-term exposures, even if the short-term exposures are to levels that would be of great concern if the exposure were long-lasting.

3.4 Risk Estimates for Indoor Air Concentrations Observed in Libby

Measurements of Libby amphibole concentrations in indoor air have been performed at a number of residential and commercial properties in Libby. Based on current data, LA fibers have been detected in one or more air samples from about 40% of the locations tested. The following table summarizes the range of values observed[4], and the excess cancer risk levels that would be associated with lifetime residential exposure to the levels that have been detected.

[4] See Attachment 1 for a detailed description of the data selection and calculation procedure.

Risks from Air in Libby

Parameter	Low Detect (5th percentile)	Average Detect (mean)	High Detect (95th Percentile)
Concentration (Total ISO s/cc)	0.00014	0.0080	0.0538
Risk (IRIS model)	9E-06	5E-04	3E-03
Risk (Berman-Crump model)	9E-05	5E-03	3E-02

As seen, in some cases the levels of LA detected are so low that there is little basis for concern. However, both average and high-end values are above the risk level of 1E-04 where EPA typically takes action under Superfund.

Comparing the risk estimates above with thosee that have been presented previously (Weis 2002a, 2002b) is difficult, since there have been a number of changes in the database as well as a change in the method used to estimate the concentration of risk-based structures (see Section 3.2, above). Nevertheless, the range of estimated PCME concentrations used to estimate risks above are generally quite similar to those used previously, as shown below.

Evaluation	Number	PCME Concentration (Detects Only) (s/cc)		
		Low	Average	High
Previous (Weis 2001b, as corrected in SRC 2002)	39 samples	0.0003	0.0017	0.0120
This report	165 properties (property average)	0.00004	0.0022	0.0150

3.5 Risk Estimate for EPA's Air Clearance Criterion

At present, EPA uses a concentration of 0.001 AHERA structures/cc as the criterion for determining that remedial activities in a home have been successful and that risks are within acceptable bounds. If this concentration were assumed to be an accurate measure of the long-term average concentration in a home, it would correspond to a risk level of about 1E-04 based on the IRIS risk model, and about 9E-04 based on the Berman-Crump risk model. However, these risks are very likely to be conservative (too high), since the air samples used to evaluate the clearance criterion are collected immediately after vigorous disturbance of dust with a leaf-blower. That is, the true long-term average concentration is likely to be much lower, and hence the true risks would also be much lower. Thus, application of this clearance criterion is considered to be highly protective of human health.

4.0 RISKS FROM ASBESTOS FIBERS IN DUST

4.1 Basic Equations

As noted earlier, asbestos fibers in dust are of potential health concern primarily because they can become resuspended in air, leading to the potential for inhalation exposure. The relationship between the concentration of fibers in air (s/cc) and the asbestos loading in dust (s/cm^2) may be expressed as a ratio:

$$K = C(air) / L(dust)$$

Clearly, the value of K is expected to be highly variable, depending on the nature of the forces that disturb the dust and cause the resuspension. Thus, it is appropriate to consider that there are a series of K values, depending on the forces acting on the dust, and that the average K factor for a house is the time weighted-average (TWA) of the K-factors for all of the different types of activities that disturb the dust:

$$K(average) = \sum K_i \cdot TWF_i$$

where:

K_i = K factor for activity type "i"
TWF_i = Time-weighting factor for activity type "i"

For the purposes of this screening assessment, two basic types of K factors are identified for a residential setting:

- the "baseline" value that applies under routine household conditions. The forces that lead to dust resuspension include thermal air currents, mechanical vibrations, and human or pet movements and activities.

- The "active cleaning" value that applies when dust is being actively disturbed by an activity such as sweeping, dusting, beating carpets or upholstery, etc.

Thus, the average value of C(air) is calculated from L(dust) as

$$\text{Average } C(air) = L(dust) \cdot (K_{baseline} \cdot TWA_{baseline} + K_{cleaning} \cdot TWA_{cleaning})$$

Given the estimate of average C(air), risks may be estimated using the various risk models above.

4.2 Parameter Values

TWA Values

The time weighting factors for "baseline" and "cleaning" activities are expected to vary widely between different homes and different people. Based on surveys of human activity patterns reported in EPA's Exposure Factors Handbook (USEPA 1977), an average of about 2 hours per day are spent in cleaning activities (Table 15-71 and Table 15-90), and this activity occurs an average of about twice per week (Table 15-51). Based on this, the TWA for cleaning is:

$$TWF_{cleaning} = (2 \text{ hrs}/24 \text{ hrs}) / (2 \text{ days}/7 \text{ days}) = 0.024$$

Defining "baseline" as all time other than that spent in active cleaning, the TWF for baseline is:

$$TWF_{baseline} = 1 - TWF_{cleaning} = 0.976$$

K Factor for Active Cleaning

Data on resuspension factors (K factors) for dust resuspension due to various types of activities are limited, and values range widely. Values published in the literature from studies at other sites are summarized in Table 4-1 (Millette and Hayes 1994). As seen in the lower half of Table 4-1, K factors for resuspension of asbestos under controlled conditions tend to fall mainly in the range of 1E-04 to 1E-06 s/cc per s/cm^2. After excluding the values associated with operating a forklift and a cable pull (these are not representative of exposures that would occur in a home), the geometric mean value of the remaining values is about 2E-05 s/cc per s/cm^2. In this regard, the maximum possible value for the K factor is 4.1E-03, which represents the case when 100% of the dust is resuspended in the air of a room that is 8 feet high. Thus, a K factor of 2E-05 represents a case where only 0.5% of the total dust is suspended in air.

Data collected by EPA at the site during Phase II Scenario 2 were intended to provide a basis for deriving a site-specific K factor for active cleaning, but the results are disappointing. In these studies, samples of air and dust were collected in several homes during various types of active cleaning activities (sweeping, vacuuming, etc). Although the ratio of the average concentration in personal air samples (total ISO s/cc) divided by the average loading in dust (total ISO s/cm2) is 1.8E-05 s/cc per s/cm^2 (similar to the value derived from the literature)[5], there were no instances in which structures were detected in both air and dust at the same home. This prevents a meaningful analysis of the relationship in paired samples (as would be preferred). This result is partly a consequence of the statistical uncertainty around each measurement, as well as the inherent variability between different homes and different types of cleaning activities. Because of the extreme variability and uncertainty in these site-specific data, these limited site-specific data are considered to be consistent with but not preferable to the literature-based estimates for active cleaning.

K Factor for "Baseline" Activities

No data were located in the literature on the K factor that describes the resuspension of dust and asbestos particles during baseline (non-active cleaning) activities in a home or workplace, although Lumley et al. (1971) reported that the concentration of PCM fibers in air of an asbestos-insulated warehouse increased about 10-fold over baseline ("hardly any activity") when there was "a lot of activity", and that moving boxes in another warehouse increase airborne levels about 3-fold compared to baseline (no activity). Based on these data, it may be concluded that the K-factor for baseline is probably about 1/3 to 1/10 that of active disturbance. Based on the screening-level K value of 2E-05 s/cc per s/cm^2 for active cleaning activities identified above, this would correspond to a baseline K-factor value of about 2E-06 to 7E-06 s/cc per s/cm^2.

An alternative value can be estimated from data collected in Libby during Phase I and Phase II studies. These studies provide data on the concentration of asbestos in indoor air (both personal and stationary monitors) and in dust in residential and commercial locations. Two approaches are possible. In the first approach, the baseline K-factor can be estimated simply by dividing the average

[5] See Attachment 1 for a detailed description of the data selection and calculation procedure.

indoor air concentration by the average indoor asbestos loading in dust[6]. The results are shown below:

Estimated K Factors for Baseline Activities in Libby

Data Collection Phase	Detection Freq.		Mean C(air) (Total ISO s/cc)	Mean L(dust) (Total ISO s/cm^2)	Ratio (Baseline K Factor)
	Air	Dust			
Phase I	60/157	198/490	0.0029	872	3.3E-06
Phase II	7/16	3/14	0.0015	213	7.2E-06

As above, because these estimates of concentrations in air and loading in dust are not paired (i.e., air and dust were not collected at the same time or place), the K-values should be interpreted only as an estimate of what may be typical under baseline conditions.

The second approach is to utilize only those data that are paired in space (i.e., both air and dust are from the same house), and to calculate the best fit line of the following form: C(air) = K·L(dust). A total of 151 such data points exist. Based on these data[7], the best fit linear regression has a slope of 1.3E-06 s/cc per s/cm^2. However, most of the data points (131 out of 151) are non-detect either for air and/or for dust, so the slope estimate is highly uncertain.

Based on these very limited data, it is concluded that the value for the value of K under baseline conditions likely falls in the range of 1E-06 to 8E-06 s/cc per s/cm^2, and a value of 4E-06 s/cc per s/cm^2 was selected to be representative. Clearly, this value should be viewed as only a rough estimate, and it should be understood that actual values could vary substantially from home to home and from time to time.

4.3 Calculation of Risk-Based Loadings for Dust

Based on the equations and inputs discussed above, the relationship between lifetime excess cancer risk and the level of asbestos structures in dust are as follows:

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[6] See Attachment 1 for a detailed description of the data selection and calculation procedure.

[7] See Attachment 1 for a detailed description of the data selection and calculation procedure.

Risk-Based Loading in Dust (s/cm^2)

Risk Level	Based on IRIS Risk Model			Based on Berman-Crump Risk Model			
	PCM/ PCME	Total ISO	Total AHERA	BCPS-s	BCPS-l	Total ISO	Total AHERA
1E-02	9,930	35,700	23,200	46,600	151	3,580	2,560
1E-03	993	3,570	2,320	4,660	15	358	256
1E-04	99	357	232	466	1.5	36	26
1E-05	10	36	23	47	0.15	3.6	2.6

For example, a person residing for 70 years in a home where the average dust content was 2,300 total AHERA structures per cm^2 would be expected to have an excess cancer risk of about 1E-03 based on the IRIS PCM risk model, and a risk somewhat higher than that based on the Berman-Crump risk model. However, it is evident from the discussions of the equations and inputs above that these risk-based values for dust should be viewed as estimates that contain a substantial amount of uncertainty. This uncertainty is due mainly to the uncertainty regarding the relationship between air and dust, as well as uncertainty in the relative contribution of different activity patterns to the average value of K. Thus, actual RBC values may be either higher or lower, depending on the actual range of conditions that exist across the community of Libby.

4.4 Risk Estimates for Dust Levels Observed in Libby

Measurements of Libby amphibole concentrations in indoor dust have been performed at a number of residential and commercial properties in Libby. Of these, LA fibers have been detected in indoor dust in about 40% of the locations (199/491). The following table summarizes the range of values observed[8], and the excess cancer risk levels that would be associated with lifetime residential exposure to the levels that have been detected.

[8] See Attachment 1 for a detailed description of the data selection and calculation procedure.

Risks from Indoor Dust in Libby

Parameter	Low Detect (5th percentile)	Average Detect (mean)	High Detect (95th Percentile)
Concentration (Total ISO s/cm^2)	29	2,147	7,823
Risk (IRIS model)	8E-06	6E-04	2E-03
Risk (Berman-Crump model)	8E-05	6E-03	2E-02

As seen, in some cases the levels of LA detected in dust are so low that there is little basis for concern, but both average and high-end values are above the risk level of 1E-04 where EPA typically takes action under Superfund.

4.5 Evaluation of Risk Associated with EPA's Action Level for Dust

At present, EPA takes active steps to clean dust on any floor of a home where the average loading exceeds 5,000 total AHERA structures per cm^2. It is important to recognize that this trigger level is not based on a consideration of the long-term acceptability of this level, since the predicted lifetime risks would be quite high (1E-03 to 1E-02, depending on which risk model is used) if it were assumed that this value was the true long-term average concentration in the home. However, actual house-wide levels are likely to be lower, since samples are collected from areas most likely to be contaminated, and decisions are based on a floor-by-floor basis rather than a house-wide average. In addition, after remediation of primary sources, it is expected that dust levels will fall over time simply as a result of routine cleaning by residents. Although the rate at which levels would fall is hard to predict, based on the expectation that most homes undergo some form of cleaned at least once per week (USEPA 1997), it is considered likely that dust levels will be substantially reduced within a few months, and likely fall to approximately background in less than a year. If so, then the lifetime excess risk contributed by a starting value of 5,000 AHERA structures/cm^2 would be on the order of 100-fold lower, probably in the range of 1E-04 to 1E-05, which are within EPA's usual target risk range. On this basis, the trigger level of 5,000 s/cm^2 for active dust remediation is considered to be fully protective of human health.

5.0 RISKS FROM ASBESTOS FIBERS IN SOIL

5.1 Basic Equations

Asbestos fibers in outdoor soil can lead to human exposure by one or more of three different pathways:

1. Resuspension from soil into outdoor air as the result of wind forces acting on exposed soil
2. Resuspension from soil into outdoor air as a result of active disturbance of the soil (e.g., working in the garden, rototilling, etc).
3. Transport of soil from outdoors into indoor dust, from which indoor activities can lead to inhalation exposure as discussed in Section 5 (above).

For erosion of asbestos from soil into outdoor air, the basic equation is:

$$C(\text{outdoor air}) = C(\text{soil}) \cdot PEF/s \cdot FPG \cdot 10^{-6}$$

where :

C(outdoor air) = concentration of asbestos structures in air (s/cc)
C(soil) = concentration of asbestos in soil (grams of asbestos per gram bulk soil)
PEF = particulate emission factor (grams of silt per m^3 of air)
s = silt content of soil (grams of silt per gram of bulk soil)
FPG = average number of asbestos fibers of per gram of asbestos
10^{-6} = conversion factor (m^3 per cc)

For transport of outdoor soil into indoor dust, the basic equation is:

$$C(\text{dust}) = ksd \cdot C(\text{soil})$$

where:

C(dust) = concentration of asbestos structures in dust (grams of asbestos per gram of dust)
ksd = fraction of indoor dust that is attributable to outdoor soil (grams soil per gram dust)
C(soil) = concentration of asbestos in soil (grams per gram)

Given an estimate of C(dust), L(dust) may be estimated as:

$$L(dust) = C(dust) / D \cdot FPG$$

where:

L(dust) = asbestos loading in dust (s/cm^2)
C(dust) = asbestos concentration in dust (grams asbestos per gram dust)
D = mass of dust per unit area (grams dust per cm^2)
FPG = Number of asbestos fibers per gram asbestos

Given L(dust), risk may be calculated as described above (see Section 4.1).

Note that this approach assumes that all asbestos that is present in soil is or may become respirable particles. This approach is an over-simplification in some cases, since some asbestos particles in soil are too large to become airborne and be inhaled. However, such large particles may become disaggregated to free fibers in the future due to weathering or mechanical forces, so the risk estimates should be considered to reflect what risks may be now (if all particles are currently fibers) or may become in the future (if some particles are currently large).

5.2 Parameter Values

TWA Values

The time that different people spend indoors and outdoors is highly variable, but the average values based on a national survey are about 1.5 hours per day outdoors, and 21 hours per day indoors (the remainder is spent in vehicles) (USEPA 1997, page 15-16). Thus, the TWF for exposure to ambient outdoor air and indoor air are approximately:

TWF(ambient outdoor air) = 1.5 hrs / 24 hr = 0.0625
TWF(indoor air) = 21 hrs / 24 hr = 0.875

The time spent engaging in outdoor activities that result in active disturbance of soil (e.g., working in the garden) is also likely to be highly variable. Based on a national survey, about 2/3 of the total respondents did not engage in gardening (USEPA 1997, Table 15-61). Of the remaining respondents, a large majority (nearly 80%) spent less that 24 hours per month gardening. Taking 12 hours per month as an estimate of what is likely to be typical for people who garden, the TWF is as follows:

TWF(disturbed outdoor air) = (12 hrs/month) / (720 hrs/month) = 0.0167

PEF Factors

The release of soil particles into outdoor air as a function of wind erosion is a complex function of the wind speed, the "roughness" of the terrain (which influences how turbulent the air flow is), the size of the exposed soil source area, and the properties of the soil (including the fraction that is covered with vegetation). Based on conservative national default values, the USEPA (1996, 2001) has calculated a default as follows:

PEF (wind erosion) = 7.4E-10 kg of soil per m^3 of air

Because the fine particles in soil are preferentially eroded in preference to the coarser soil particles, it is assumed the wind-eroded soil particles all belong to the silt fraction (< 50 um in diameter).

Mathematical models exist for calculating PEFs for various types of active disturbances of soil (plowing a field, driving a vehicle on a dirt road, etc.) (Cowherd et al. 1985), but these are all very crude models and none are likely to be particularly relevant for the types of active disturbances that may affect a resident while working in their yard. Therefore, the PEF for active soil disturbance was simply assumed to be 100 times higher than for wind erosion:

PEF(active disturbance) = 100 · PEF(wind erosion) = 7.4E-08 kg of soil per m^3 of air

As will be seen below, the overall risk from asbestos in soil is not very sensitive to this assumption, so efforts to derive a more reliable value do not appear to be warranted.

Ksd Value

Indoor dust is composed of particles derived from many different sources, and only a fraction of the total is derived from exterior soil. Studies on the relationship between arsenic and lead in soil at numerous mining sites in the Rocky Mountain west suggest that in most cases, the fraction of dust derived from soil is likely to be about 20%-40%. Thus, for the purposes of the screening calculations at this site, a value of 30% (Ksd = 0.3) is assumed. Note that this assumes that the outdoor yard soil is uniformly contaminated with asbestos. In cases where only a portion of the yard is contaminated, the total soil contribution to dust may still be 30%, but only a fraction of that will contain asbestos. Thus, the value of 30% is likely to be conservative in many cases.

FPG value

The number of fibers per gram (FPG) of any particular size category of asbestos per gram total asbestos varies widely as a function of the size distribution of the asbestos particles composing the sample. At this site, an estimate of FPG for each risk-based fiber type was derived by estimating as follows:

$$FPG(x) = \frac{x}{\sum_{i=1}^{N} \left(w_i^2\right) \cdot l_i \cdot \delta \cdot 1E-12}$$

where:

N	= total number of LA fibers observed in samples of air and dust from Libby
x	= total number of fibers of type "x" observed in the total set of N fibers
w_i	= width (um) of LA fiber "i"
l_i	= length (um) of LA fiber i"
δ	= density of LA fibers (3.1 grams/cc)
1E-12	= conversion factor (cc per um^3)

Based on a total of over 8,300 structures observed at Libby, estimates of FPG for each of the three main risk-based fiber types is as follows:

Fiber Type	Estimated FPG
Total	2.9E+10
PCM/PCME	9.0E+09
BCPS-s	3.9E+09
BCPS-l	1.3E+09

Silt Fraction

The fraction of a soil sample that is composed of particles that are silt-sized or smaller varies widely from location to location. Site-specific measurements of the silt content of soils in Libby have not yet been performed. However, the U.S. Department of Agriculture Soil Survey Program database for Montana does provide some data on the silt fraction for soils collected in and around Lincoln County (USDA 2003). The fraction of silt in surface soil (depth < 25cm) ranged from 0.23 to 0.95, with a mean of 0.70. The mean value of 0.70 was used in the screening-level risk calculations for soil.

Dust Loading

The amount of dust on a surface (g/cm^2) is expected to vary widely from location to location and from time to time, depending on the types and rates of dust deposition on surfaces and on the frequency and thoroughness of cleaning. At this site, a set of 20 samples of dust were collected by vacuuming five template areas of 100 cm^2 each (total area = 500 cm^2) from carpets and floors in residential properties in Libby, and weighing the amount of dust collected. Values ranged from a minimum of non-detect (< 0.0002 mg/cm^2) to a maximum of 0.06 mg/cm^2, with a mean of about 0.01 mg/cm^2. The mean value (1E-05 g/cm^2) was used in the screening-level risk calculations for soil.

5.3 Calculation of Risk-Based Concentrations for Soil

Based on the equations and inputs discussed above, the risk-based concentrations of asbestos structures in soil (expressed as mass percent) are as follows:

Risk-Based Concentrations in Soil (mass percent)

Risk Level	Based on IRIS Risk Model	Based on Berman-Crump Risk Model
1E-02	36%	3.7%
1E-03	3.6%	0.37%
1E-04	0.36%	0.04%
1E-05	0.04%	0.004%

An interesting point to note is that most of the risk (about 86%) from asbestos in soil is attributable to the transport of the soil to indoor dust rather than the exposures which occur to asbestos in ambient or disturbed outdoor air. This is mainly because the time spent outdoor exposed to ambient air or to air near disturbed soil are quite small compared to the time spent indoors.

5.4 Risks Estimates for Soil Levels Observed in Libby

Measurements of Libby amphibole concentrations in outdoor yard soil have been performed at a number of residential and commercial properties in Libby using polarized light microscopy (PLM). Of these properties, LA fibers have been observed in one or more soil samples from about 20% of the locations (64 out of 328). In most of these cases, the levels of LA in soil have been too low to quantify (these are reported as "Trace" or "<1%"), which probably corresponds with concentrations that are mainly in the 0.1-1% range. Based on the screening-level assumptions described above, soil concentrations in this range are predicted to correspond with excess lifetime cancer risk levels of 3E-05 to 3E-04 (IRIS risk model) to 3E-04 to 3E-03 (Berman Crump risk model). In a few cases, levels of asbestos were high enough to quantify, with several values estimated to be ....

5.5 Estimated Risks at EPA's Action Level for Soil

At present, EPA removes and replaces soils that are estimated to contain 1% or more asbestos (grams per gram). Based on the assumptions described above, this level of soil contamination poses an excess cancer risk of about 3E-04 based on the IRIS PCM risk model and about 3E-03 based on the Berman-Crump risk model. However, these calculations are based on several assumptions that may tend to overestimate actual hazard. Most important is the assumption that the entire yard is contaminated with asbestos, while most sites evaluated to date tend to have asbestos in only one or two parts of the yard. If the total area contaminated was only 1/10 of the yard, this would tend to reduce the amount of asbestos entering house dust from yard soil, and risk estimates might be as much as 10-fold lower. In addition, the calculations do not account for the effects of snow cover and frozen ground, both of which tend to reduce transport of soil into indoor dust. Based on these considerations, it is concluded that an action level of 1% asbestos in soil is likely to capture areas of major concern from this medium, although the possibility for subsequent removal at a lower action level have not been entirely excluded at this time.

6.0 SUMMARY AND DISCUSSION

Reliable prediction of human health risk due to asbestos in environmental media (air, dust, soil) is very difficult. This is because of uncertainty at all stages of the risk assessment process. Table 6-1 lists the main sources of uncertainty, and provides a judgement about how large and in which direction the error associated with the uncertainty might be. Inspection of this table emphasizes the many different sources of uncertainty, and how uncertain the risk estimates are (especially those associated with expected releases from soil or dust). Risk managers and the public should take these uncertainties into account when interpreting the calculations in this document.

Despite this uncertainty, the screening level calculations reported in this appendix provide a starting point for quantitative risk-based decision-making at the site. More specifically, the calculations have shown that there are numerous locations in Libby where concentrations of Libby amphibole in air, dust and/or soil are above a level of potential health concern, and indicate that the current triggers for action used by EPA as well as the "clearance" criteria used to declare a location to be acceptable are protective and reasonable.

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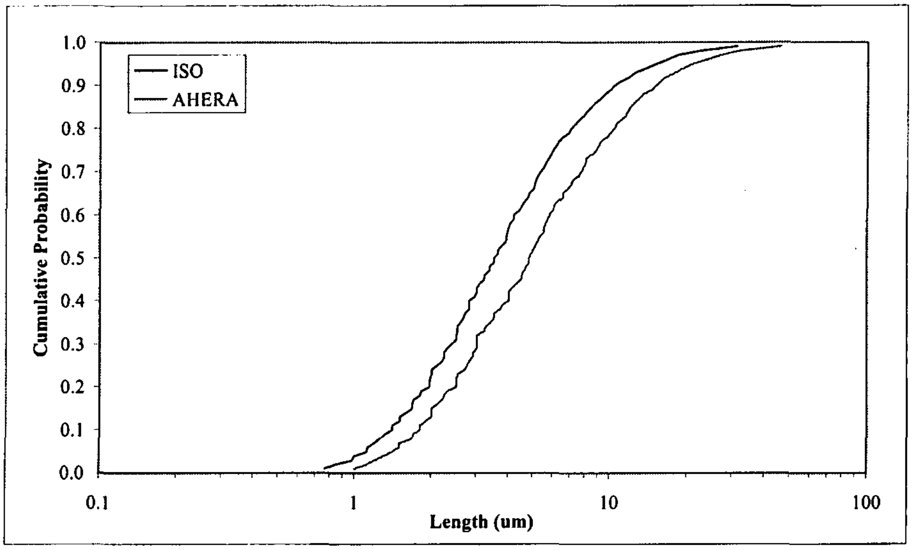
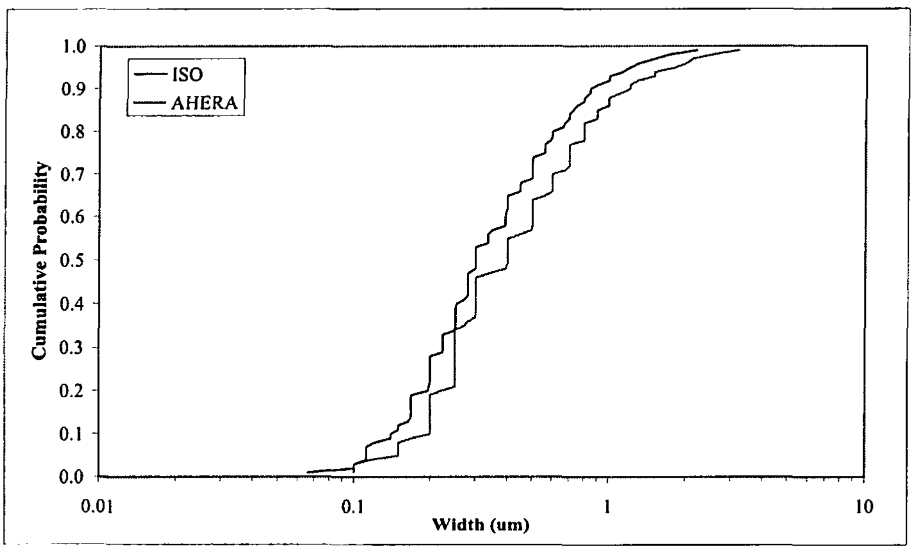
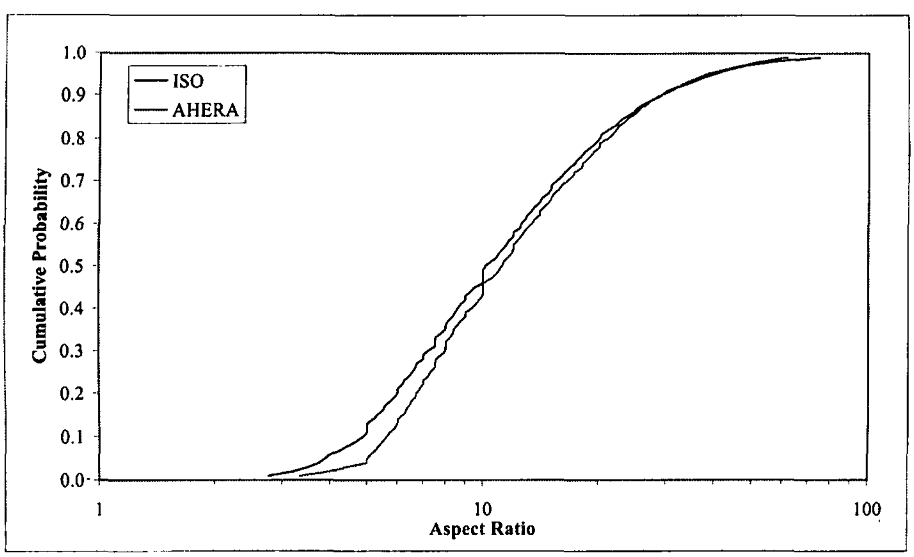
Figure 3-1
Structure Characteristic Distributions







Dist graphs 7-31-03.xls: graphs
8/14/2003

Figure 3-2. Correlation of Observed and Calculated PCME Fiber Levels

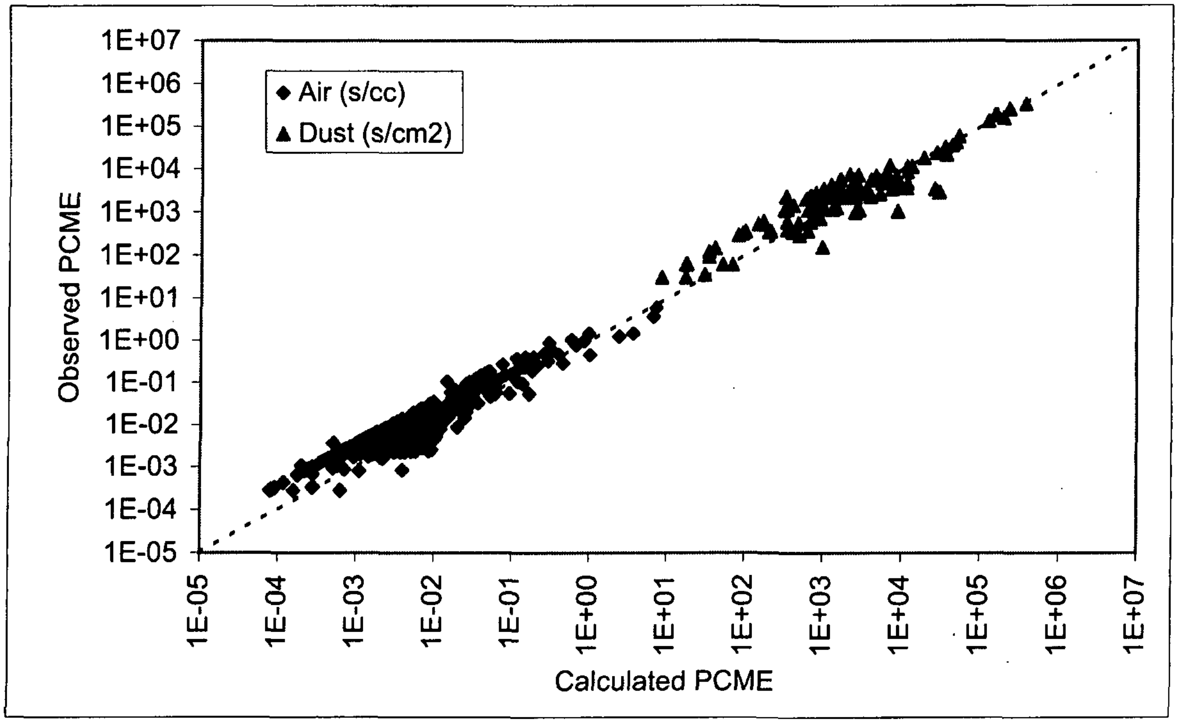


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TABLE 4-1. K FACTORS REPORTED AT OTHER SITES

Contaminant	Activity	K (s/cc per s/cm^2)
^{131}I-labeled dust	Active work in confined space	4.3E-05
Beryllium	Warehouse inventory	2E-02
Alpha emitters	Walking	4.9E-04
Uranium particles	Cart movement	1.45E-04
Chrysotile dust in a warehouse	Handling contaminated materials	2.0E-03 to 4.2E-03
Microorganisms	Air jet Moist mopping	1.2E-03 2.0E-04
Zinc Sulfide powder	Vigorous sweeping	1.9E-04
Asbestos (controlled studies)	Gym/athletic activities	2.4E-05
	Cleaning a storage area	3.1E-05
	Operating a forklift in a warehouse	3.6E-03
	Cable pull	1.4E-05
	Broom sweeping	7.1E-05
	Conventional carpet cleaning	3.9E-06

Source: Values are compiled from numerous reports as summarized by Millette and Hayes (1994)

TABLE 6-1. SUMMARY OF UNCERTAINTIES

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
Inhalation of fibers in air	C(air)	Based on typical number of grid openings counted (10-40), estimates have moderate to high statistical uncertainty. Values may vary as a function of time and location.	Medium	Either higher or lower
	Cancer Unit Risk Factors	Dependence of cancer risk on fiber size and type of asbestos not certain; more than 10-fold difference between different models	Medium-Large	Unknown
	Non-cancer reference concentration	No value is currently available; dependence on fiber size and type is unknown	Large	Underestimate non-cancer risk
Exposure to fibers from disturbance of indoor dust	C(dust)	Based on typical number of grid openings counted (10-40), estimates have moderate to high statistical uncertainty. Values may vary as a function of time and location.	Medium	Either higher or lower
	K Factor for active cleaning	Value is highly variable, depends on details of source, disturbance, and location; values from literature span 2 orders of magnitude; site specific estimate of mean is within literature range	Large	Either higher or lower
	K Factor for "baseline" residential activities	Nearly no information from literature. Site value is crude estimate of "typical". Actual values may vary widely.	Very Large	Either higher or lower
	TWF for active cleaning and baseline exposures	Based on national default values. Activity patterns in Libby may be different.	Small	Either higher or lower

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
Exposure to asbestos in outdoor air due to releases from soil	C(soil)	Quantification of asbestos in soil is difficult; current methods are only semi-quantitative. Estimates do not account for the presence of large (non-respirable) particles, since these may become respirable in the future.	Medium	Either higher or lower
	PEF for release of asbestos from soil to ambient outdoor air	Based on conservative national default values. Conditions in Libby may be different. For example, the factor assumes 50% vegetative cover, while actual site conditions may vary. The factor does not consider effect of snow cover or frozen ground.	Small	More likely to overestimate than underestimate
	Silt content of soil	Based on county wide statistics. Conditions in Libby may differ.	Small	Either higher or lower
	TWF for exposure to ambient outdoor air	Based on national default values. Activity patterns in Libby may be different.	Small	Either higher or lower
Exposure to asbestos in outdoor air due to releases from soil	TWF for active soil disturbance	Based on national default values for gardening. Activity patterns in Libby may be different.	Small	More likely to overestimate than underestimate
	PEF for release of asbestos from soil to outdoor air following active disturbance	Assumed value, very uncertain. Nevertheless, because exposure frequency and duration are assumed to be small, overall contribution to risk is small.	Small	Unknown

Pathway	Variable	Basis of Uncertainty	Likely Magnitude in Overall Risk Estimate	Likely Direction of Error
Exposure to asbestos in soil following transfer to indoor dust	Transfer of asbestos from soil into indoor dust	Based on studies on lead and arsenic at other sites. Conditions in Libby may vary. Assumes that entire yard is contaminated with asbestos. If only hot-spots exist, risks will be lower. Does not quantitatively consider effect of snow, frozen ground, or vegetative cover.	Large	Either higher or lower; probably higher in most cases.
	Estimate of fibers per gram of asbestos	Based on site data.	Small.	Unknown.
	Dust loading	Based on limited site data. Values are highly variable between locations, and are also likely to vary with time.	Large	Either higher or lower.